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CANADA

OPERATIONAL RESEARCH DIVISION

DIRECTORATE OF OPERATIONAL RESEARCH
(CORPORATE, AIR & MARITIME)

ORD PROJECT REPORT NO. PR-9803

AN ANNOTATED CHRONOLOGY OF STATISTICAL CONSULTATION ON THE CLASS SIGHT/ CARL GUSTAV ACQUISITION

BY

E.J. Emond

FEBRUARY 1998

OTTAWA, CANADA

National Defence Défense nationale

OPERATIONAL RESEARCH DIVISION

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by

E.J. Emond

Recommended by: J.G. Moscrip
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OTTAWA, ONTARIO

FEBRUARY 1998

ABSTRACT

This project report was written to document the statistical consultation provided over a period of two years on the final stages of the acquisition of a laser sight for the Carl Gustav anti-armour weapon. The paper has been structured around a series of internal memoranda which detail the problems encountered and the gradual progress towards a solution. Besides providing a case study of an actual statistical consultancy project, the report includes lessons and experiences which may be of value in future.

RÉSUMÉ

Ce rapport a été écrit pour documenter la consultation statistique donnée pendant une période de deux années sur les étapes finales de l'acquisition d'une visée laser pour l'arme anti-armure Carl Gustav. Le rapport a été organisé autour d'une série des memorandums internes qui expliquent les problèmes rencontrés et l'avancement graduel vers une solution. En plus, on présente un dossier d'un projet véritable de consultation statistique et le rapport comprends les leçons et les expériences qui pourraient être utiles dans le futur.

EXECUTIVE SUMMARY

1. This report has been written specifically to document the statistical consultation provided to the Directorate of Land Requirements (DLR) over a period of two years on the final stages of the acquisition of the Computerized Laser Sight (CLASS), a laser range-finding optical sight to be fitted to the Carl Gustav 84 mm weapon. As such, the project report has been structured in a chronological sequence around a series of internal memoranda which detail ongoing results and problems.

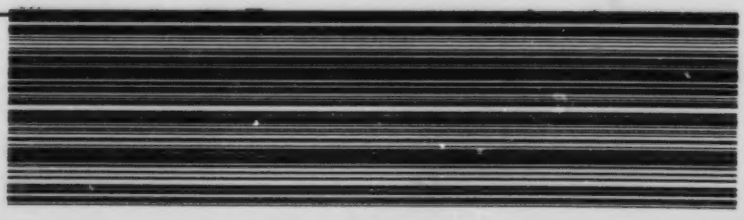
2. The initial focus of activity on the CLASS sight acquisition testing was boresight retention. After the shock of firing, it was found that there was a misalignment between the sight and the weapon which potentially could cause accuracy problems. During user acceptance testing at CFB Gagetown in January 1996, a more serious problem occurred when a series of several rounds impacted the ground well short of the intended target. Both problems were the subject of intensive analysis and discussion, leading to a series of strapdown firings at the Proof and Experimental Test Establishment in Nicolet over the following months. Eventually, with the cooperation of Computing Devices Canada and staff of several directorates within NDHQ, both problems were solved and DND acquired the CLASS sight for the Carl Gustav.

3. The series of ten memoranda presented in this report document the gradual progress towards a solution to the problems encountered in the acquisition of the CLASS sight for the Carl Gustav weapon. Problems with boresight retention were the initial focus of attention but these were quickly displaced when it became evident that there were serious accuracy issues associated with firing at short ranges and low ammunition temperatures. Both problems were finally overcome, but it required hard work, patience, and spirit of cooperation of all the individuals involved in the project.

4. For the statistical consultant, there are some important lessons to be learned from the experiences on this project. Although at first the boresight retention analysis seemed like a fairly minor item, it quickly escalated due to the continued failure of the CLASS sight in user trials. Every aspect of the analysis came under close scrutiny from the opposing parties and no assumption was left unchallenged. The only defence to claims of bias and error was professional competence and clear and open reporting of analysis procedures and results.

5. A good example of the problems and requirements involved in statistical consulting on an important and contentious project is given by the issue of outlier determination. The outlier memorandum of 29 AUG 97 was the product of a week of intensive effort. It required familiarity with the data gathered at previous trials, an understanding of the practicalities of actually carrying out the firings, a knowledge of the technical factors involved and a strong grasp of the theoretical issues. The two lessons that emerged are the need for the analyst to become familiar with the practical issues by personally attending the trials when possible, and the importance of understanding the mathematical basis of statistical procedures.

6. In addition to documenting the issues involved in solving the specific technical aspects of the CLASS sight acceptance procedure, this report provides an illustrative case history of the nature of statistical consultation in DND. Lessons learned include the importance of having a sound theoretical knowledge of statistics, backed up by practical experience and a flexible analysis tool such as SAS. Also of importance are the ability to communicate clearly both verbally and in writing, in order to minimize misunderstandings and produce practical and sound analyses. Openness and professional competence are vital in fostering a relationship of trust and cooperation with all parties involved in order to find positive solutions to difficult problems.



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AN ANNOTATED CHRONOLOGY OF STATISTICAL CONSULTATION ON THE CLASS SIGHT / CARL GUSTAV ACQUISITION

INTRODUCTION

1. This report has been written specifically to document the statistical consultation provided to the Directorate of Land Requirements (DLR) over a period of two years on the final stages of the acquisition of the Computerized Laser Sight (CLASS), a laser range-finding optical sight to be fitted to the Carl Gustav 84 mm weapon. As such, the research note has been structured in a chronological sequence around a series of internal memoranda which detail ongoing results and problems.

2. Besides documenting the actual results and methodology over the period from November 1995 to November 1997, it is hoped that this report will provide both an interesting case study of statistical consultancy in the Department of National Defence (DND) as well as help in future cases of similar nature in anticipating logical and practical pitfalls.

BACKGROUND

3. The Carl Gustav 84 mm weapon has been a DND infantry weapon for many years. It was bought as a man portable anti-armour weapon intended for use at short range. Because of poor accuracy due to aiming error and in particular the difficulty of estimating target range by eye, the Carl Gustav is not effective beyond 300 metres, thus severely limiting its usefulness in combat. The addition of the CLASS sight to the Carl Gustav was intended to overcome this drawback, enabling the weapon to function usefully out to ranges of 700 metres or more.

4. Although the purchase of the CLASS sight was an 'off the shelf' contract, it was nevertheless necessary to conduct acceptance trials to ensure that the system would perform as expected. Accuracy of the system in a fixed mount was specified in the contract between DND and the manufacturer, Computing Devices Canada (CDC), as a hit probability of 0.80 against a standard 2.3 metre square NATO target at a range of 700 metres. In addition, initial experience with the sight indicated that a potential problem existed with respect to the retention of boresight alignment after firing.

BORESIGHT DISPLACEMENT ANALYSIS - NOVEMBER 1995

5. In early November 1995, the Directorate of Land Requirements project director, Captain R. Hart, approached Mr. Emond of the Directorate of Mathematics and Statistics (DMS) with a request for assistance in the analysis of boresight displacement data. In an effort to correct excessive boresight displacements observed after firing the Carl Gustav weapon, test firings had been conducted with three guns and three sights and a combination of procedures which included adjustments to mounting brackets and the application of bonding agent to sight mountings. An analysis of data collected at these test firings was performed using the SAS statistical analysis package, in particular the General Linear Model procedure. Results were communicated to DLR both verbally and by memorandum, as shown in Figures 1(1) to 1(7) below.

6. The main conclusion from this first analysis of boresight displacement data was that the problem persisted despite various attempts to stabilize the sight mounting on the gun. Note the importance of having a flexible and reliable statistical package like SAS which allowed a simple yet statistically sophisticated analysis of the data in a matter of one or two days.

MEMORANDUM

ORA 3563-41302-1 (DMS)

10 Nov 95

DLR 5-7

Attention: Capt. Hart

ANALYSIS OF DATA FROM CARL GUSTAV TRIAL

1. DMS has performed a statistical analysis of data from recent trials of the Carl Gustav weapon. Annex A lists the raw data. There are four 'sets' within the data, defined as follows. Set 1 consists of thirty baseline firings with combinations of three different guns and three different optical sights. (Serials 1 through 7) Set 2 consists of ten firings with two gun/sight combinations, after adjustments to mounting brackets. (Serials 8 and 9) Set 3 consists of nine firings with the same two gun/sight combinations as in Set 2, after bonding was applied to the sight mountings. (Serials 10 and 11) Set 4 consists of fifteen firings again with the same two gun/sight combinations as in Sets 2 and 3, after further bonding was applied. The measured azimuth and elevation adjustments for each firing are given in milliradians. Displacement in milliradians is calculated as the vector sum of the azimuth and elevation adjustments.

2. A statistical procedure, analysis of variance, was applied to the data to determine if there was any significant effect on displacement due to set, gun or sight. Since the trial design was unbalanced, the standard analysis of variance packages cannot be used. Therefore, the SAS procedure known as the General Linear Model (GLIM) was applied. This procedure is applicable to trials data where the design is unbalanced. Detailed results are given in Annex B.

3. The following tables give the mean displacement over the four sets, the three guns, and the three sights, respectively. The analysis of variance procedure in each case determines whether the observed differences between the means are statistically significant.

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FIGURE 1(1) MEMORANDUM OF 10 NOV 95

TABLE I

MEAN DISPLACEMENT OVER SETS

SET	N	Mean Displacement (Mils)
1	30	0.79
2	10	0.78
3	9	0.89
4	15	0.61

There is no statistically significant effect on mean displacement due to the variable SET. (The F distribution tail area for the test of the null hypothesis was 0.24.)

TABLE II

MEAN DISPLACEMENT OVER GUNS

GUN	N	Mean Displacement (Mils)
1	9	0.57
2	28	0.87
3	27	0.70

There is a statistically significant effect on mean displacement due to the variable GUN. (The F distribution tail area for the test of the null hypothesis was 0.05.)

FIGURE 1(2) MEMORANDUM OF 10 NOV 95

TABLE III

MEAN DISPLACEMENT OVER SIGHTS

SIGHT	N	Mean Displacement (Mils)
1	28	0.85
2	27	0.76
3	9	0.47

There is a statistically significant effect on mean displacement due to the variable SIGHT. (The F distribution tail area for the test of the null hypothesis was 0.05.)

4. In summary, the trial data show a statistically significant effect on mean displacement due to both the individual sights and guns, but no significant effect due to the four different sets. It may be concluded that the various adjustments and applications of bonding had no significant effect on the problem of sight displacement.

E.J. Emond

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Defence Scientist
DMS
992-4730

Attachments:

Annex A - Class Boresight Results Raw Data
Annex B - General Linear Models Procedure Class Level Information

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FIGURE 1(3) MEMORANDUM OF 10 NOV 95

ANNEX A
TO ORA 3563-41302-1 (DMS)
DATED 1C NOV 95

CLASS BORESIGHT RESULTS
RAW DATA

SET	SIGHT	GUN	AZIMUTH	ELEVATION	DISPLACEMENT
1	1	1	1.4	1.4	1.98
1	1	1	0.0	0.0	0.0
1	1	1	0.2	0.0	0.2
1	1	1	1.0	0.2	1.02
1	1	1	0.4	0.2	0.45
1	2	2	1.0	0.2	1.02
1	2	2	1.0	0.2	1.02
1	2	2	1.0	0.8	1.28
1	2	2	0.4	1.6	1.65
1	1	3	0.0	0.8	0.8
1	1	3	0.0	0.2	0.2
1	1	3	0.2	0.4	0.45
1	1	3	0.4	0.4	0.57
1	1	3	0.2	0.2	0.28
1	3	3	1.0	0.4	1.08
1	3	3	0.6	0.2	0.63
1	3	3	0.4	0.0	0.4
1	3	3	0.0	0.0	0.0
1	3	3	0.0	0.6	0.6
1	1	2	1.2	0.4	1.26
1	1	2	1.8	0.0	1.8
1	1	2	1.8	1.4	2.28
1	1	2	0.2	0.8	0.82
1	3	1	0.2	0.0	0.2
1	3	1	0.0	0.4	0.4
1	3	1	0.2	0.0	0.2
1	3	1	0.4	0.6	0.72
1	2	3	0.2	0.4	0.45
1	2	3	0.8	0.8	1.13
1	2	3	0.4	0.6	0.72
2	2	2	0.8	0.8	1.13
2	2	2	0.6	0.6	0.85
2	2	2	1.0	0.4	1.08
2	2	2	1.0	0.2	1.02
2	2	2	0.4	0.0	0.4

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FIGURE 1(4) MEMORANDUM OF 10 NOV 95

SET	SIGHT	GUN	AZIMUTH	ELEVATION	DISPLACEMENT
2	1	3	1.0	0.2	1.02
2	1	3	0.8	0.2	0.82
2	1	3	0.6	0.2	0.63
2	1	3	0.4	0.2	0.45
2	1	3	0.2	0.4	0.45
3	2	2	0.2	0.2	0.28
3	2	2	0.6	0.0	0.6
3	2	2	0.8	0.0	0.8
3	2	2	0.0	0.0	0.0
3	2	2	0.2	0.4	0.45
3	1	3	0.8	0.2	0.82
3	1	3	0.6	0.6	0.85
3	1	3	1.8	0.6	1.90
3	1	3	1.8	1.4	2.28
4	1	3	0.4	-0.2	0.45
4	1	3	-0.2	0.4	0.45
4	1	3	-0.2	-0.2	0.28
4	1	3	0.0	-0.4	0.4
4	1	3	-0.2	0.8	0.82
4	2	2	0.2	-1.6	1.61
4	2	2	-0.4	0.4	0.57
4	2	2	0.4	-0.6	0.72
4	2	2	-0.2	-0.2	0.28
4	2	2	0.4	-0.6	0.72
4	2	2	0.4	0.4	0.57
4	2	2	-0.6	-0.6	0.85
4	2	2	-0.4	0.0	0.4
4	2	2	0.2	-0.4	0.45
4	2	2	0.4	0.4	0.57

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FIGURE 1(5) MEMORANDUM OF 10 NOV 95

ANNEX B
TO ORA 3563-41302-1 (DMS)
DATED 16 NOV 95

General Linear Models Procedure
Class Level Information

Class	Levels	Values
SET	4	1 2 3 4
GUN	3	1 2 3
SIGHT	3	1 2 3

Number of observations in data set = 64

General Linear Models Procedure

Dependent Variable: DISPL

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	3.35970872	0.47995839	1.96	0.0767
Error	56	13.69493248	0.24455237		
Corrected Total	63	17.05464120			

R-Square	C.V.	Root MSE	DISPL Mean
0.196997	65.15784	0.494522	0.75896063

General Linear Models Procedure

Dependent Variable: DISPL

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SET	3	1.06681086	0.35560362	1.45	0.2369
GUN	2	1.54496145	0.77248072	3.16	0.0501
SIGHT	2	1.56787040	0.78393520	3.21	0.0481

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FIGURE 1(6) MEMORANDUM OF 10 NOV 95

General Linear Models Procedure

Level of SET	N	DISPL Mean	DISPL SD
1	30	0.78707699	0.58413787
2	10	0.78480436	0.28300396
3	9	0.88676922	0.74185267
4	15	0.60881359	0.32952241

Level of GUN	N	DISPL Mean	DISPL SD
1	9	0.57422519	0.61159513
2	28	0.87415939	0.51509331
3	27	0.70107372	0.48553627

General Linear Models Procedure

Level of SIGHT	N	DISPL Mean	DISPL SD
1	28	0.84773596	0.64168831
2	27	0.76319535	0.39775268
3	9	0.47006653	0.32621640

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FIGURE 1(7) MEMORANDUM OF 10 NOV 95

PLANNING FOR THE FIRST USER ACCEPTANCE TRIALS

7. An extensive user trial of the Carl Gustav with the CLASS sight was planned for January of 1996. This trial was planned and executed by DLR and the Trials and Evaluation group at CFB Gagetown. Because of previous involvement with the analysis of boresight displacement data, DMS was asked to comment on the statistical aspects of the segment of the trial which dealt with the retention of boresight alignment after firing. In order to fully investigate the contribution of different sights and guns and to provide sufficient data to produce a definitive conclusion, a full factorial experimental design was recommended using three representative sights, three representative guns, and five replications. Randomization of the gun and sight combinations was also recommended in order to neutralize the effects of varying experimental conditions. The memorandum shown below in Figures 2(1) to 2(2) was sent to DLR in early January of 1996.

8. Of particular interest in the 15 JAN 96 memorandum was the inclusion of acceptance criteria for boresight displacement performance. Two criteria were developed by DMS based on the operational requirement to retain boresight alignment in accordance with accuracy requirements at short range. The first criterion was based on the need to eliminate large boresight deviations, defined as those in excess of one milliradian, and specified an upper limit of five percent for such observations. The second criterion was included to insure that the overall distribution of displacement observations would be acceptable in a more global sense. This was achieved by requiring that the mean displacement plus a multiple of the standard deviation be less than 1.2 milliradians, thus ensuring that a majority of the displacement observations would be below this value.

MEMORANDUM

ORA 3563-41302-1 (DMS)

15 Jan 96

DLR 5-7

Attention: Capt. Hart

CARL GUSTAF BORESIGHT RETENTION TRIALS

1. As discussed in earlier meetings between Captain Hart and Mr. Emond, DMS recommends a balanced full factorial experimental design with replications as the most accurate and efficient way to test for retention of boresight in the upcoming Carl Gustaf CLASS sight trials. A good balance between the statistical requirements and practical considerations will be attained by using three weapons and three sights, with five replications of each weapon/sight combination. This results in a requirement for 45 rounds in total. By using three guns and three sights, we can account for boresight retention variability due to the two main factors (gun and sight). The five replications account for variability due to all other sources. The main goal is to obtain an accurate statistical picture of the boresight retention performance of the system. The secondary goal is to determine the contribution to the overall variability due to both guns and sights.

2. The guns and sights used in the trials should be typical and representative. The best way to ensure this is to draw each gun and sight at random from a large number of guns and sights, if possible. Failure to ensure that the experimental weapons and sights are typical and representative of the entire population of each can destroy the validity of trial results.

3. Whenever practical, all assignments in the trials should be randomized to avoid the possibility of systematic distortion of results. In particular, the sequence of gun/sight combinations for testing should be randomized to eliminate any distortion due to changes in experimental conditions over time. A random sequence has been obtained by DMS as requested and is given below.

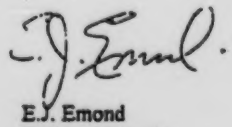
1/2

FIGURE 2(1) MEMORANDUM OF 15 JAN 96

Serial	Combination	Replications
1.	Gun 1 , Sight 2	5
2.	Gun 3 , Sight 3	5
3.	Gun 3 , Sight 2	5
4.	Gun 1 , Sight 3	5
5.	Gun 2 , Sight 3	5
6.	Gun 3 , Sight 1	5
7.	Gun 2 , Sight 2	5
8.	Gun 1 , Sight 1	5
9.	Gun 2 , Sight 1	5

4. Details of all trials should be carefully recorded. This is one of the most important yet most often overlooked aspects of a trial. All measurements of azimuth and elevation deviations should be recorded along with the quadrant and a diagram if possible. Any relevant observations and details should be carefully noted along with the results of each measurement.

5. Although it is hoped that the trials will show that previous boresight deviation problems have been corrected, it is prudent to give some thought to the analysis and interpretation of the trial results. For an individual firing, a boresight total displacement of one milliradian is considered to be undesirable. In previous trials, individual displacements as high as 2.28 milliradians occurred and 18 out of 64 exceeded one milliradian. It is proposed that two separate criteria be used to judge the boresight retention performance in the upcoming trials. The first is that no more than five out of the 45 individual boresight displacement measurements may exceed one milliradian. This number was derived as the acceptance criterion for a simple test of hypothesis that the probability that an individual displacement will exceed one milliradian is at most 0.05. The second criterion is that the sample mean plus 1.645 times the sample standard deviation for boresight displacement not exceed one milliradian. (The upper limit may be increased to 1.2 milliradians if desired, to allow for the effect of a small number of outliers.) This criterion ensures that the variability of the boresight displacement is within reasonable bounds.



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992-4730

2/2

FIGURE 2(2) MEMORANDUM OF 15 JAN 96

CONTENTIOUS ISSUES FROM THE GAGETOWN USER TRIAL

9. The problem of boresight retention was pushed back to secondary importance when at the Gagetown trial of January 1996 the Carl Gustav with CLASS sight was unable to hit any of the targets at the 700 m. range, with numerous rounds impacting the ground in front of the targets. The problem was so severe that this aspect of the accuracy trials was called off. The accuracy problem would later become the focus of DMS attention on this project. However, a useful amount of boresight retention data was collected as planned.

10. In early June of 1996, DMS conducted an analysis of boresight retention data collected at the January 1996 Gagetown trial and concluded that performance was statistically no better than in previous trials. These findings were written up in a memorandum dated 17 JUN 96. See Figures 3(1) to 3(3) below. Note that in the spring of 1996 DMS ceased to exist as a directorate due to internal cutbacks and reorganization within the Director General of Operations Research (DGOR). Mr. Emond was moved to the Central Operational Research Team (CORT) but continued to perform the role of statistical consultant to DND clients.

11. Due to the ground impact problems in the Gagetown acceptance trial and the continued failure of the CLASS sight to retain boresight within prescribed limits, it became clear in June 1996 that Mr. Emond's involvement as a statistical consultant in this project would amount to more than the nominal few weeks originally foreseen. In normal circumstances, brief consultations are provided to clients such as DLR under blanket agreements and without formal requests for assistance. Since the nominal few weeks had already been provided and a requirement for more intensive involvement was looming, DLR at this time formally requested continued assistance from DGOR in a memorandum dated 27 JUN 96, presented below as Figure 4. DGOR strongly supported the request and Mr. Emond was directed to provide the required assistance.

Memorandum

ORA 3563-41302-1 (DGOR/CORT)

17 Jun 96

DLR 5-7 (Capt Hart)

ANALYSIS OF DATA FROM BORESIGHT RETENTION TRIALS

1. Boresight retention results from the CLASS sight trials held in Gagetown early in 1996 have been analyzed as requested. The raw data are listed in Annex A to this memorandum for quick reference.

2. It was originally planned to perform 5 replications of a full factorial design with three guns and three sights, for a total of 45 observations. Two acceptance criteria were proposed, both based on the requirement that the weapon/sight system retain boresight after firing, to at least within 1 milliradian. The first criterion was that the mean sight displacement plus 1.645 times the sight displacement standard deviation not exceed 1 milliradian. The second criterion was that no more that 5 out of 45 individual displacements exceed 1 milliradian.

3. The recommended trial plan discussed above was not followed. Four sights and three guns were used and only for sight number 4 was a full set of observations obtained. Only 39 observations were obtained rather than 45. The table below gives the mean sight displacement in mils for each weapon/sight combination tested.

TABLE I : MEAN SIGHT DISPLACEMENTS IN MILS

		SIGHT				
		1	2	3	4	
GUN	1	N/A	0.37	0.65	0.68	0.56
	2	N/A	0.00	N/A	0.29	0.16
	3	1.54	N/A	0.56	0.62	0.91
		1.54	0.20	0.61	0.53	0.60

FIGURE 3(1) MEMORANDUM OF 17 JUN 96

4. As indicated in Table I, the overall average sight displacement was 0.60 mils. The standard deviation was 0.56 mils. The value of the mean displacement plus 1.645 times the standard deviation is 1.52, indicating a failure to pass the first acceptance criterion.

5. A total of 11 observations out of 39 were equal to or greater than 1 milliradian. This indicates a failure to pass the second acceptance criterion as well.

6. It is instructive to compare the sight displacement performance of the acceptance trials to the 64 values obtained in earlier tests at Gagetown. Briefly, the null hypothesis that there was no significant difference between the distribution of values obtained in the two data sets, is accepted at the 95 percent confidence level using a Kolmogorov Smirnov test.

CONCLUSIONS

7. The performance of the CLASS sights in retaining boresight to within 1 milliradian at the Gagetown acceptance trials was statistically no better than in earlier tests. Boresight retention to within one milliradian was judged to have been a failure under two separate criteria. In 28 percent of the observations, the boresight net displacement equalled or exceeded one milliradian.

8. There has been some discussion about the results of the boresight acceptance trials if the data from sight number one is not used. Although such a procedure would not be justified unless there were extraordinary and compelling reasons, it is of interest to note that in the present case this would not change the overall conclusion that the boresight retention results did not meet the one milliradian criteria. (The mean and standard deviation of the remaining 34 observations are 0.466 mils and 0.393 mils respectively. The resulting value of the mean plus 1.645 times the standard deviation is 1.11 which exceeds the acceptance value of 1.0. Also, there were 6 out of the 34 values that equalled or exceeded 1 mil, thus exceeding the acceptance upper limit for the second criterion.)

E. J. Emond

E. J. Emond
DS/DGOR/CORT
2-4730

Att: Annex A

FIGURE 3(2) MEMORANDUM OF 17 JUN 96

ANNEX A
to ORA 3563-41302-1 (CORT)
dated: 17 Jun 96

TABLE A-I
Boresight Retention Results

Serial	Round	Gun	Sight	Elev (mils)	Azim (mils)	Sight Displ (mils)
1	1	3	1	-2.6	-0.4	2.63
1	3	3	1	1.2	0.6	1.34
1	6	3	1	-0.4	-1.0	1.08
1	9	3	1	-0.4	1.6	1.65
1	11	3	1	-1.0	0.0	1.00
2	2	1	4	-0.4	-0.4	0.57
2	4	1	4	0.0	0.0	0.00
2	5	1	4	0.6	0.2	0.63
2	7	1	4	-1.0	0.2	1.02
2	8	1	4	1.0	0.6	1.17
3	10	2	4	0.0	0.2	0.20
3	12	2	4	0.0	-0.2	0.20
3	13	2	4	0.0	-0.4	0.40
3	14	2	4	0.0	-0.2	0.20
3	15	2		0.2	0.4	0.45
4	16	3	4	-1.0	1.0	1.41
4	17	3	4	0.4	0.4	0.57
4	19	3	4	0.2	0.2	0.28
4	20	3	4	0.0	-0.4	0.40
4	22	3	4	-0.2	-0.4	0.45
5	18	1	2	0.0	-0.8	0.80
5	21	1	2	0.0	0.0	0.00
5	23	1	2	-0.4	0.0	0.40
5	24	1	2	-0.6	-0.2	0.63
5	26	1	2	0.0	0.0	0.00
6	25	3	3	-1.2	-0.2	1.22
6	27	3	3	0.0	-0.4	0.40
6	28	3	3	0.6	0.4	0.72
6	29	3	3	-0.2	0.0	0.20
6	30	3	3	0.2	-0.2	0.28
7	31	1	3	-1.0	0.4	1.08
7	33	1	3	0.4	-0.2	0.45
7	34	1	3	-0.2	0.4	0.45
7	36	1	3	0.2	-0.2	0.28
7	38	1	3	-0.8	0.6	1.00
8	32	2	2	0.0	0.0	0.00
8	35	2	2	0.0	0.0	0.00
8	37	2	2	0.0	0.0	0.00
8	39	2	2	0.0	0.0	0.00

FIGURE 3(3) MEMORANDUM OF 17 JUN 96

Forwarded to: DGOR

Project: 3543-41302-1

Charged to: ORD

3563-41302-1 (DLR)

27 Jun 96

(1) DGOR

REQUEST FOR SUPPORT FOR DATA ANALYSIS

1. Mr Ed Emond was requested on an informal basis to assist in the development of the plan of test for the CLASS sight trial and to examine elements of the trial data. His support has proven to be invaluable in interpreting the results and making sense of conflicts between contractor's claims and the trial officer's data. He has been particularly valuable in offering sound and impartial advice to both the project staff and to the contractor.

2. The CLASS sight project is to provide a day/night fire control system for the 84mm Carl Gustaf launcher. It is being pursued in response to an urgent operational requirement to equip Canadian forces in the former Yugoslavia with a means of engaging armoured vehicles at ranges to 700m. Progress in the CLASS sight project has become critically dependent on determining the cause of failure of the sight. Key to this is the advice on trial design and the data analysis provided by Mr Emond.

3. As this workload now looks as if it will exceed the scope of the previous informal arrangements, it is requested that Mr Emond be formally tasked to support this project. It is anticipated that there will be a requirement for further work on the design of tests to be conducted at PETE and for extensive analysis of the results. Once this phase is completed and modifications made to the sight, further testing at PETE will be required. This workload is likely to require 3-5 days work per month until Sep and may require attendance at some of the firings in PETE which will be funded at project expense.

4. The support of DGOR and in particular Mr Emond has been outstanding. Your continued support to this project is requested.

Thankyou

Howie

H.J. Marsh
Col
DLR
945-7642

(3) Copy to Mr Emond, his letter, TST-2 - Ed - pls raised PDF/IPCS for trial and contact TST-2 to arrange a briefing
Yet another for!

(2) DOR (CAM)
A very nice letter!
This is clearly a high priority task and we should undertake it. Please prepare reply for my signature. Mr Emond should brief SMC on this soon.

DGOR 2/7/96.

FIGURE 4 DLR REQUEST FOR SUPPORT OF 27 JUN 96

12. Due to controversy concerning the conclusions with respect to boresight retention from the Gagetown trial, DLR requested an analysis of additional data collected by the trials officer while evaluating other aspects of the system. This analysis was performed in early July of 1996. The resulting memorandum to DLR reporting the results is presented below in Figures 5(1) to 5(5). Although some improvement was found with more observations falling in the acceptable range, the additional data reinforced the earlier conclusion that the CLASS sight continued to fail the acceptance criteria with respect to boresight retention.

13. For the statistical consultant, there are some important lessons to be learned from the experiences on this project up to the summer of 1996. Although at first the boresight retention analysis seemed like a fairly minor item, it quickly escalated due to the continued failure of the CLASS sight in user trials. Every aspect of the analysis came under close scrutiny from the opposing parties and no assumption was left unchallenged. The only defence to claims of bias and error is professional competence and clear and open reporting of analysis procedures and results. In addition, the creation of unambiguous acceptance criteria for boresight retention performance based on operational requirements was found to be of vital importance.

Memorandum

ORA 3563-41302-1 (DGOR/CORT)

16 Jul 96

DLR 5-7 (Capt Hart)

ANALYSIS OF ADDITIONAL BORESIGHT RETENTION DATA

Ref: Memorandum ORA 3563-41302-1 (DGOR/CORT):Analysis of Data From Boresight Retention Trials, dated 17 Jun 96.

1. In Ref, a statistical analysis of 39 boresight retention observations from the Carl Gustav Class Sight acceptance trials at CFB Gagetown in early 1996, concluded that the sight did not meet the acceptance criteria and that results were not significantly different from earlier tests. During the acceptance trials, a further 85 firings were conducted to test other aspects of sight performance. Because of the interest in boresight retention and thanks to the intelligent initiative of the trials officer, boresight retention data were collected for each of these firings. Data from these additional 85 firings were forwarded to Mr. Emond by DLR and this memorandum documents the results of the statistical analysis.

2. Sight displacement data for the 85 additional observations are given in Annex A. The mean sight displacement for these 85 observations is 0.57 mils and the standard deviation is 0.544 mils. The corresponding values for the 39 earlier observations were 0.60 mils and 0.56 mils respectively. The value of the mean displacement plus 1.645 times the standard deviation for the 85 additional observations is 1.465 which exceeds the first acceptance criterion. A total of 18 sight displacement values exceeded 1 mil. The second acceptance criterion is based on the requirement for a low probability of a sight displacement in excess of 1 mil. The value of 18 observations greatly exceeds the second acceptance criterion.

3. A Kolmogorov-Smirnoff test was applied to determine whether the 85 values differed significantly in overall distribution from either of the two earlier sets of data. No significant difference was found between the 85 values and the 39 values from the Gagetown acceptance trials. However, there was a significant difference between the 85 values and the 64 values from earlier tests. The 85 values included more displacements in the zero to 0.4 mils range, indicating some improvement in boresight displacement performance.

4. It is of some interest to look at the performance of individual gun/sight combinations within the 85 additional observations. Only four of 12 possible combinations occurred. Gun 1 was used only with Sights 1 and 4. The other two combinations were Gun 2/Sight 2 and Gun 3/Sight 3. The table below gives detailed results.

1/2

FIGURE 5(1) MEMORANDUM OF 16 JUL 96

TABLE I

BORESIGHT DISPLACEMENT RESULTS FOR GUN/SIGHT COMBINATIONS

	GUN 1	GUN 2	GUN 3
SIGHT 1	n = 18 $\bar{x}$ = .42 mils s = .37 mils	x x x	x x x
SIGHT 2	x x x	n = 26 $\bar{x}$ = .21 mils s = .41 mils	x x x
SIGHT 3	x x x	x x x	n = 31 $\bar{x}$ = .97 mils s = .50 mils
SIGHT 4	n = 10 $\bar{x}$ = .52 mils s = .47 mils	x x x	x x x

5. Only the Gun 2/Sight 2 combination displays good boresight retention performance. The Gun 1 results are marginal and the Gun 3 results are poor.

CONCLUSIONS

6. Analysis of 85 additional boresight displacement observations from the Gagetown acceptance trials indicates no significant differences from the 39 observations analyzed earlier. In both cases the Class sight failed to meet the two acceptance criteria for boresight retention. Comparison of the 85 observations with earlier tests shows some improvement in boresight retention performance in that a higher proportion of the values fall in the 0 to 0.4 mils range.

E.J. Emond

E.J. Emond
DS/DGOR/CORT
2-4730

Att: Annex A

2/2

FIGURE 5(2) MEMORANDUM OF 16 JUL 96

ANNEX A
to ORA 3563-41302 (CORT)
DATED: 16 JUL. 96

TABLE A-I

ADDITIONAL BORESIGHT RETENTION DATA

	Rd.	Gun	Sight	Azim. (mils)	Elev. (mils)	Displ. (mils)
1	288	1	4	-0.196	0.000	0.196
2	289	3	3	-0.784	-0.196	0.808
3	290	2	2	0.000	-0.392	0.392
4	291	1	4	-0.392	-1.372	1.427
5	292	2	2	0.000	0.000	0.000
6	293	3	3	-0.784	0.000	0.784
7	294	2	2	0.588	0.000	0.588
8	295	1	4	0.392	0.980	1.055
9	296	3	3	-1.176	-0.392	1.240
10	297	1	4	0.000	-0.196	0.196
11	298	3	3	1.372	-0.392	1.427
12	299	2	2	0.000	-0.392	0.392
13	300	1	4	0.000	0.392	0.392
14	301	3	3	-0.980	-0.588	1.143
15	302	2	2	0.196	0.000	0.196
16	303	2	2	0.000	0.000	0.000
17	304	3	3	0.000	0.000	0.000
18	305	1	4	-0.196	0.392	0.438
19	260	2	2	0.000	0.000	0.000
20	261	1	1	0.000	-0.196	0.196
21	262	3	3	0.000	-0.392	0.392
22	263	1	1	0.000	0.392	0.392
23	264	2	2	0.000	0.000	0.000
24	265	3	3	0.784	0.196	0.808
25	266	2	2	0.000	0.000	0.000
26	229	2	2	0.000	-0.588	0.588
27	230	1	1	0.000	-0.980	0.980
28	231	3	3	-0.392	-0.588	0.707
29	232	2	2	0.000	0.000	0.000
30	233	1	1	0.000	1.176	1.176
31	234	3	3	0.980	0.392	1.055
32	235	2	2	0.000	0.000	0.000
33	236	1	1	0.000	0.000	0.000

FIGURE 5(3) MEMORANDUM OF 16 JUL 96

34	237	3	3	0.000	-0.392	0.392
35	238	3	3	-0.392	-0.980	1.055
36	239	2	2	0.000	0.000	0.000
37	240	1	1	-0.980	0.196	0.999
38	241	3	3	0.784	-1.176	1.413
39	242	1	1	0.000	0.000	0.000
40	243	1	1	0.392	0.000	0.392
41	244	3	3	-0.196	1.176	1.192
42	245	2	2	0.000	-0.588	0.588
43	246	1	1	0.196	0.196	0.277
44	247	3	3	-0.980	0.392	1.055
45	248	1	1	0.000	-0.392	0.392
46	249	2	2	0.000	0.000	0.000
47	250	3	3	-0.588	-0.392	0.707
48	251	1	1	0.000	0.588	0.588
49	252	2	2	0.000	0.000	0.000
50	253	3	3	0.588	1.372	1.493
51	254	1	1	0.000	-0.588	0.588
52	255	3	3	-0.588	-0.784	0.980
53	256	1	1	0.000	0.000	0.000
54	257	3	3	-1.176	-0.588	1.315
55	258	1	1	0.000	0.000	0.000
56	259	3	3	-0.392	0.196	0.438
57	306	1	4	0.588	0.588	0.832
58	307	2	2	0.000	0.000	0.000
59	308	3	3	-1.568	-0.588	1.675
60	309	2	2	-0.196	0.000	0.196
61	310	1	4	-0.392	-0.588	0.707
62	311	3	3	-0.392	-0.588	0.707
63	312	1	4	0.000	0.000	0.000
64	313	2	2	0.000	0.000	0.000
65	314	3	3	-0.980	-0.196	0.999
66	279	2	2	0.000	-1.960	1.960
67	280	1	4	0.000	0.000	0.000
68	281	3	3	0.588	-0.196	0.620
69	282	3	3	-0.392	-0.196	0.438
70	283	2	2	0.000	0.000	0.000
71	284	2	2	-0.196	-0.196	0.277
72	285	3	3	-0.196	0.980	0.999
73	286	2	2	0.000	0.000	0.000
74	287	3	3	0.000	-0.588	0.588
75	268	1	1	0.000	-0.196	0.196
76	269	2	2	0.000	-0.392	0.392
77	270	3	3	-1.372	2.156	2.556

A-2

FIGURE 5(4) MEMORANDUM OF 16 JUL 96

78	271	1	1	0.196	0.000	0.196
79	272	3	3	0.588	-1.372	1.493
80	273	2	2	0.000	0.000	0.000
81	274	1	1	0.000	-0.784	0.784
82	275	3	3	-1.176	-0.588	1.315
83	276	1	1	0.000	-0.392	0.392
84	277	2	2	0.000	0.000	0.000
85	278	3	3	0.196	-0.196	0.277

A-3

FIGURE 5(5) MEMORANDUM OF 16 JUL 96

AMMUNITION QUESTIONS AND COLD TEMPERATURE TRIALS

14. In an effort to find a way ahead, all parties involved in the CLASS sight acquisition attended a series of meetings in the summer of 1996. In addition to the DLR representative and Mr. Emond of CORT acting as DND statistical consultant, the other parties consisted of technical and management staff from Computing Devices Canada (CDC), project manager from the Directorate of Artillery Systems Program Management (DASPM) and a representative from Supply and Services Canada. There was some disagreement between the parties on the next step, with controversy centring around the performance of Bofors and SNC 84 mm ammunition, particularly in cold weather.

15. After many discussions it was decided to carry out a trial at the Proofing and Experimental Test Establishment (PETE) in order to provide data necessary for the eventual resolution of the ground impact problem observed at Gagetown. It was decided to fire 5 rounds of four different ammunition types : Bofors live rounds, Bofors practice rounds, SNC live rounds and SNC practice rounds. The firings would use a fixed mount to eliminate operator aiming error. All rounds would be fired at a range of 700 metres and all ammunition would be conditioned to -40 C in order to investigate the effect of ammunition temperature on accuracy.

16. The first PETE trial was held in October 1996 and was attended by representatives of DLR, DASPM and CDC as well as Mr. Emond of DGOR/CORT. The trial provided a great amount of information and coincidentally provoked many more questions. A detailed memorandum dated 6 NOV 96 was written to DLR summarizing the findings and is presented below as Figures 6(1) to 6(8).

Memorandum

ORA 3563-41302-1 (CORT)

6 Nov 96

Distr List

ANALYSIS OF CARL GUSTAV FIRING DATA FROM 22 OCT 96 TRIAL

1. As part of the project to equip the Carl Gustav 84mm weapon with the CLASS sight, a series of strap-down firings was carried out at PETE (Nicolet) on October 22, 1996. In attendance were the PETE test personnel headed by CWO Deroy, two representatives of Computing Devices Canada, Mr Steve Marr representing DSSPM, Capt Rick Hart of DLR, and Mr Ed Emond of DGOR/CORT.

2. Complete firing data and results have been received from PETE, supplemented by data collected by the NDHQ team at the trial. Annex A to this memorandum contains the results and the analysis carried out by Mr Emond.

3. Based on the analysis in Annex A and a meeting of all parties on 31 Oct 96, the following conclusions have been reached.

a) The trial results showed a statistically significant increase in the variability of measured muzzle velocity for both Bofors and SNC produced rounds when conditioned to -40 C, as compared to proofing rounds conditioned to +21 C. For the 22 rounds conditioned to -40 C the mean muzzle velocity was 238.3 metres per second with a standard deviation of 6.7 metres per second. An analysis of proofing data from Sept 95 showed that the mean muzzle velocity for 34 rounds conditioned to 21 C was 244.5 metres per second with a standard deviation of 3.4 metres per second. A statistical test rejected the null hypothesis of equality of variances at the one percent level.

b) It was agreed that due to the apparent variability of muzzle velocity at -40 C, it would not be reasonable to evaluate the accuracy of the Carl Gustav with the CLASS sight at extreme cold temperatures. A further series of test firings at the same 700 metre range and at charge temperatures varying downward from 0 C is recommended in order to determine a temperature at which the variability of the muzzle velocity is small enough to allow a valid accuracy trial of the Carl Gustav weapon with the CLASS sight. A sample size of at least 12 rounds at each temperature is recommended due to the observed high variability in the 22 Oct trial.

c) It was agreed that for all future test firings on this project, the ammunition will be 551 HEAT rounds produced by SNC. This will simplify both the trials and the analysis.

FIGURE 6(1) MEMORANDUM OF 6 NOV 96

d) Analysis of trial results was hampered severely by the fact that seven out of 22 rounds missed the target. It is recommended that the target size be increased by PETE in order to ensure that all future firings at the 700 metre range produce measurable impact points.

e) CLASS boresight retention was determined after each firing in the 22 Oct trial by measurement of aim point on the target. A total of 21 measurements were made. Only one observation exceeded one milliradian, round B2 at 1.21 milliradians. Three other observations exceeded 0.7 milliradians. Although these results are technically acceptable according to previously determined acceptance criteria, it is recommended that boresight retention continue to be measured and that at least two different and representative Carl Gustav guns be used, before any consideration is given to formally accepting CLASS performance in boresight retention.

E.J. Emond.

E.J. Emond
DS/DGOR/CORT
2-4730

Distr List

Action

DLR 5-7:Attn:Captain Hart

Info

DOR(CAM)
L/CORT

FIGURE 6(2) MEMORANDUM OF 6 NOV 96

ANNEX A
TO ORA 3563-41302-1 (CORT)
DATED 6 NOV 96

ANNEX A - RESULTS AND ANALYSIS OF 22 OCT 96 TRIAL

1. The following two pages are from the PETE trial report. The first page gives firing data for all 22 rounds. Note that rounds W1 and W2 were warmup rounds, fired at 41.0 and 42.0 mils elevation respectively. It was decided after the two warmup rounds to use an elevation of 41.5 mils for the trial.

2. The target height above ground was 0.9 metres. The target itself was 12 feet square. Rounds B4 and B5 impacted the ground short of the target. By actual measurement, round B4 impacted 8.5 metres in front of the target and round B5 impacted 32.5 metres in front of the target. Round S3 grazed the bottom of the target. Rounds S4 and S5 impacted the ground at distances estimated from radar data of 16 metres and 14 metres respectively. Round B6 was fired at an elevation of 42.5 mils and flew over the target. Round S6 passed over the top of the target at a height estimated at 0.5 metres from video data.

3. The second page gives detailed meteorological data. In general, the conditions remained fairly constant throughout the test firings. The air temperature increased from 6.2 C to 7.5 C over the day; Barometric pressure dropped from 1014.8 to 1012.7 over the day; air density and humidity were constant; and the wind remained as a tailwind throughout the day, dropping in speed from around 20 to 26 km. per hour to around 13 to 17 km. per hour.

FIGURE 6(3) MEMORANDUM OF 6 NOV 96

Proof and Experimental Test Establishment
Centre d'Essai et d'Expérimentation
Nicolet

Instruction # 96-3188A

File/Dossier
10081-1 TD 4627

Description: 84 mm Carl Gustaf

Rd.	Time fired	PETE Boresight X (mils)	PETE Boresight T.E. (mils)	Point of strike Hor. (m)	Point of strike Ver. (m)	CLASS sight #	CLASS sight Hor. (m)	CLASS sight Ver. (m)	Muzzle Velocity (m/s)	Return (m/s/m)	Time of flight (sec.)	Motor ignition (m.)
W-1	10:36	0.0	41.0	0.41	-1.07	41	-	-	229.4	0.105	2.42	18.7
W-2	10:54	0.0	42.0	-0.45	1.26	41	-0.05	-0.06	247.6	0.118	2.34	17.8
Lot FFV82-L01-03												
B-1	11:01	0.0	41.5	0.55	-1.29	41	-	-	243.0	0.137	2.41	13.5
B-2	11:07	0.0	41.5	0.77	-1.59	41	-0.60	-0.60	243.4	0.121	2.41	20.0
B-3	11:27	0.0	41.5	0.29	-1.21	41	0.10	0.08	243.8	0.124	2.39	19.3
B-4	11:33	0.0	41.5	Miss target		41	-0.02	0.10	228.8	0.104	2.43	21.2
B-5	11:41	0.0	41.5	Miss target		41	-0.07	0.06	226.4	0.109	2.37	18.9
			Mean:	0.54	-1.36		-0.15	-0.09	237.0		2.40	18.6
			S.d.:	0.24	0.20		0.31	0.34	8.8		0.02	3.0
Lot CA-87H02-04												
S-1	13:34	0.0	41.5	0.32	-1.32	43	-0.10	-0.08	238.0	0.099	2.38	18.5
S-2	13:39	0.0	41.5	-0.06	-1.15	43	-0.29	-0.40	234.0	0.073	2.38	12.3
S-3	14:02	0.0	41.5	Miss target		43	0.05	-0.04	240.7	0.100	2.38	17.4
S-4	14:08	0.0	41.5	Miss target		43	0.14	-0.02	226.5	0.088	2.38	17.0
S-5	14:20	0.0	41.5	Miss target		43	0.00	0.00	229.4	0.069	2.35	13.9
			Mean:	0.13	-1.24		-0.04	-0.11	233.7		2.37	15.8
			S.d.:	0.27	0.12		0.16	0.17	5.9		0.01	2.8
Lot FFV82B01-01												
B-6	14:46	0.0	42.5	Miss target		40	0.00	0.00	247.8	0.107	2.33	15.1
B-7	15:00	0.0	41.5	0.28	-1.30	40	0.00	0.00	241.4	0.101	2.37	14.4
B-8	15:04	0.0	41.5	0.36	-0.85	40	0.00	0.00	236.4	0.088	2.39	17.0
B-9	15:08	0.0	41.5	-0.41	-1.51	40	-0.05	0.12	236.4	0.122	2.39	14.5
B-10	15:14	0.0	41.5	-0.52	-1.68	40	0.00	0.00	241.2	0.109	2.37	14.8
			Mean:	-0.07	-1.34		-0.01	0.02	240.6		2.37	15.2
			S.d.:	0.46	0.36		0.02	0.05	4.8		0.02	1.1
Lot CA-95J06-04												
S-6	15:19	0.0	41.5	Miss target		40	0.19	-0.64	246.8	0.080	2.30	18.2
S-7	15:25	0.0	41.5	1.22	0.90	40	0.00	0.50	239.5	0.099	2.32	16.8
S-8	15:29	0.0	41.5	0.96	0.66	40	-0.17	0.00	243.0	0.088	2.33	14.0
S-9	15:34	0.0	41.5	1.42	1.11	40	0.00	0.08	242.9	0.112	2.32	18.5
S-10	15:38	0.0	41.5	-0.31	-0.33	40	-	-	236.6	0.092	2.35	21.3
			Mean:	0.82	0.59		0.01	-0.02	241.8		2.32	17.8
			S.d.:	0.78	0.64		0.15	0.47	3.9		0.02	2.7

REMARKS:
The rounds were conditioned at -40°C during a period of 32 hours before firing.
Target distance from the muzzle: 700 m
Firing azimuth 4 300 mils
Coordinates of point of strike were measured on target.

2/2

FIGURE 6(4) MEMORANDUM OF 6 NOV 96

Meteo Quotidienne
pour le 22 octobre 1996

Heure Locale	Temp. Sec(C)	Pression (HPa)	Densite (%)	Humidite (%)	Vent (Deg)	Vent (Km/h)
800	6.2	1014.8	102.8	100	43	26
815	6.3	1014.7	102.8	100	46	23
830	6.3	1014.5	102.8	100	45	22
845	6.4	1014.5	102.7	100	50	20
900	6.4	1014.3	102.7	100	44	18
915	6.5	1014.4	102.7	100	41	17
930	6.7	1014.2	102.6	100	47	20
945	6.9	1014.1	102.5	100	49	20
1000	7.0	1014.1	102.4	100	49	20
1015	7.1	1014.0	102.4	100	50	21
1030	7.2	1014.1	102.4	100	50	20
1045	7.1	1014.2	102.4	100	53	19
1100	7.1	1014.1	102.4	100	47	19
1115	7.2	1013.8	102.3	100	40	19
1130	7.3	1013.7	102.3	100	46	20
1145	7.4	1013.7	102.2	100	39	17
1200	7.4	1013.7	102.2	100	44	17
1215	7.5	1013.6	102.2	100	45	18
1230	7.6	1013.4	102.1	100	49	16
1245	7.8	1013.3	102.1	100	48	16
1300	7.8	1013.3	102.0	100	49	14
1315	7.8	1013.2	102.0	100	56	18
1330	7.7	1013.1	102.1	100	48	14
1345	7.7	1013.2	102.1	100	55	18
1400	7.7	1013.1	102.1	100	55	17
1415	7.7	1012.9	102.1	100	45	16
1430	7.7	1012.7	102.0	100	53	16
1445	7.7	1012.6	102.0	100	50	16
1500	7.7	1012.7	102.0	100	43	15
1515	7.7	1012.5	102.0	100	54	18
1530	7.7	1012.5	102.0	100	48	16
1545	7.7	1012.6	102.0	100	47	14
1600	7.5	1012.7	102.1	100	47	13

FIGURE 6(5) MEMORANDUM OF 6 NOV 96

ANALYSIS OF MUZZLE VELOCITY DATA

4. The following table gives the vertical impact point for each of the 41.5 mil elevation firings, some of which have been estimated from ground impact data. Also the measured muzzle velocities are given. Figure A-1 is a plot of the muzzle velocity versus vertical impact distance along with a fitted least squares regression line. The correlation coefficient for these values is 0.76, indicating a moderate linear dependence of vertical impact distance on muzzle velocity.

VERTICAL IMPACT DISTANCE AND MUZZLE VELOCITY

Serial	Ident	Vertical Impact (m.)	Muzzel Velocity (m. per sec.)
1.	B1	-1.29	243.0
2.	B2	-1.59	243.4
3.	B3	-1.21	243.8
4.	B4	-3.03 *	228.6
5.	B5	-3.86 *	226.4
6.	S1	-1.32	238.0
7.	S2	-1.15	234.0
8.	S3	-1.90 *	240.7
9.	S4	-3.29 *	226.5
10.	S5	-3.22 *	229.4
11.	B7	-1.30	241.4
12.	B8	-0.85	236.4
13.	B9	-1.51	236.4
14.	B10	-1.68	241.2
15.	S6	2.33 *	246.8
16.	S7	0.90	239.5
17.	S8	0.66	243.0
18.	S9	1.11	242.9
19.	S10	-0.33	236.6

Correlation coefficient for impact versus muzzle velocity : 0.76

*Values with an asterisk are estimates, based on an impact angle of 2 degrees. Target height was 3.66 m. (12 ft.) and target bottom was 0.9 m. above ground. Distances measured from target centre.

Round B4 : Impacted ground 8.5 m. in front of target.
Round B5 : Impacted ground 32.5 m. in front of target.
Round S3 : Grazed bottom of target.
Round S4 : Impacted ground 16 m. in front of target.
Round S5 : Impacted ground 14 m. in front of target.
Round S6 : Passed approx. 0.5 m. above target.

FIGURE 6(6) MEMORANDUM OF 6 NOV 96

FIGURE A-1

Vertical Impact Distance versus Muzzle Velocity
Rounds pre-conditioned to -40 degrees C.

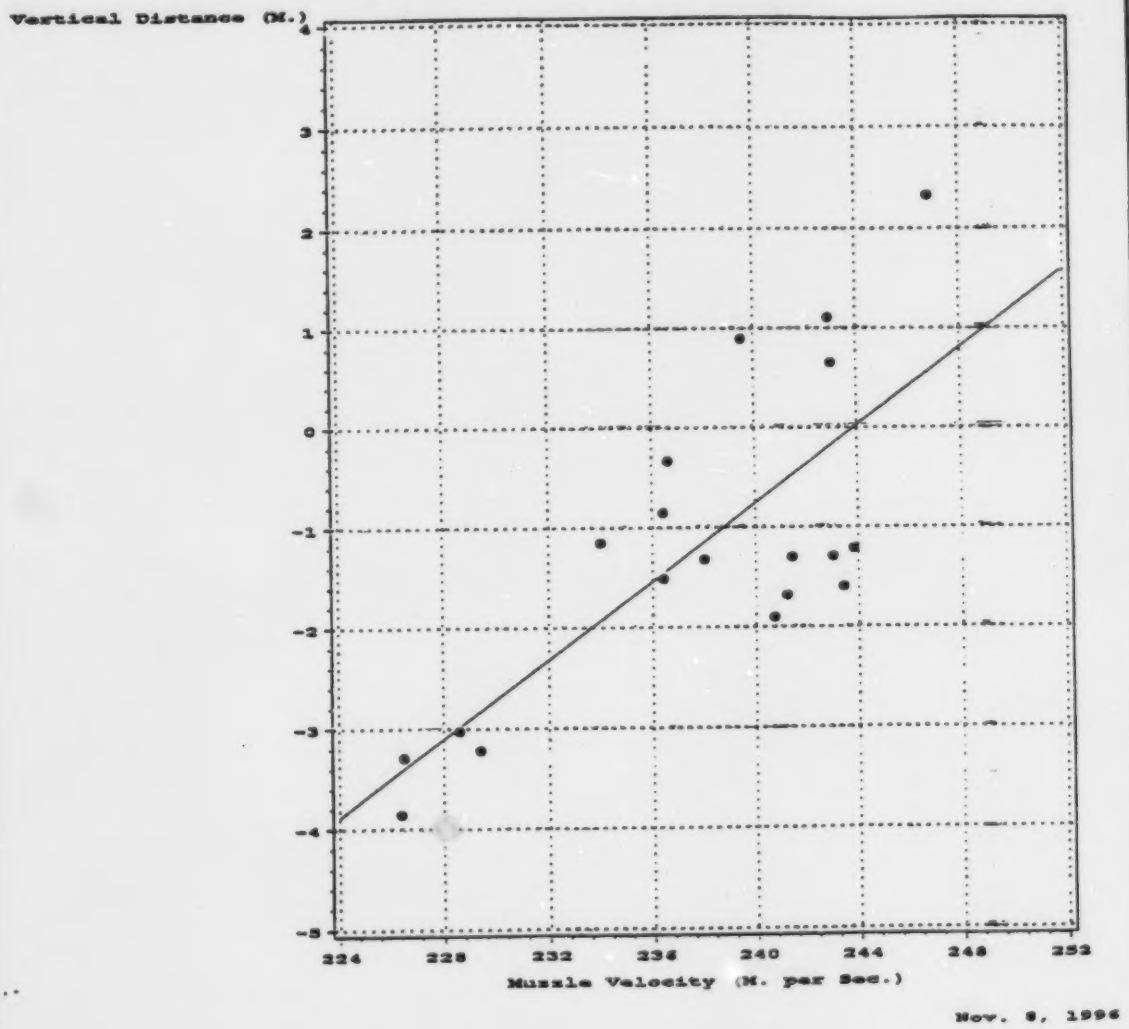

FIGURE 6(7) MEMORANDUM OF 6 NOV 96

BORESIGHT DISPLACEMENT DATA

5. The following table gives the measured CLASS boresight displacements for 21 observations. Boresight displacement for rounds B1 and S10 are not given in the PETE data sheet but were estimated at the time as approximately zero.

Round	Horizontal (m.)	Vertical (m.)	Displacement (Milliradians)
W2	-0.05	-0.08	0.13
B1	0.0	0.0	0.0
B2	-0.60	-0.60	1.21
B3	0.10	0.08	0.18
B4	-0.02	0.10	0.15
B5	-0.07	0.06	0.13
S1	-0.10	-0.08	0.18
S2	-0.29	-0.40	0.71
S3	0.05	-0.04	0.09
S4	0.14	-0.02	0.20
S5	0.0	0.0	0.0
B6	0.0	0.0	0.0
B7	0.0	0.0	0.0
B8	0.0	0.0	0.0
B9	-0.05	0.12	0.19
B10	0.0	0.0	0.0
S6	0.19	-0.64	0.95
S7	0.0	0.50	0.71
S8	-0.17	0.0	0.24
S9	0.0	0 .08	0.11
S10	0.0	0.0	0.0

FIGURE 6(8) MEMORANDUM OF 6 NOV 96

17. Out of the total of 42 rounds fired in the October 96 PETE trial, 7 rounds failed to hit the 3.66 metre (12 feet) square target despite the fixed mount and near ideal conditions. Five of the live rounds impacted the ground short of the target and two of the practice rounds flew over the target. Measured muzzle velocity showed significantly higher variation than that measured from proofing data. It was concluded that ammunition performance not in accordance with the Bofors range tables at low ammunition temperature was the likely cause of the ground impact problem.

18. While providing a great deal of valuable data towards the resolution of the accuracy problems encountered in the Gagetown user trial, the PETE trial results presented a dilemma for both DND and CDC. DND had contracted for an off the shelf system which was to provide a fixed-mount hit probability of 0.80 on a 2.3 metre square target at 700 metres. The PETE results showed that such a hit probability was impossible to achieve at low ammunition temperatures with the current ammunition. CDC had signed a contract which promised system performance which was not achievable for reasons having nothing to do with the CLASS sight. It was clear that both parties would have to work to find a way out of this stalemate.

19. Fortunately, the experience at PETE and subsequent meetings between the parties had fostered a relationship of mutual trust and cooperation. A resolution was worked out wherein DND would lower the acceptance criteria to a level achievable with current ammunition and CDC would make modifications to the CLASS sight internal algorithms to account for lower than expected vertical impact points when operating at low ammunition temperatures. It was decided that only SNC-produced live ammunition from the same lot would be used in all future firings, thus eliminating variability due to ammunition to the extent possible. The issue of reducing ammunition variability would be postponed until the CLASS project was completed.

20. The period just after the October 96 PETE trial was a critical one for the CLASS sight project and a valuable lesson emerged. This was the importance of having the analysts attend the trial and collect the data first hand. The subsequent analysis of the data was greatly enhanced but more importantly in this case was the mutual trust and understanding which developed between the parties. From the 96 PETE trial to the present, work on the CLASS sight project has been characterized by mutual cooperation rather than mistrust and suspicion.

21. As a footnote to the October 96 PETE trial, the original

problem of excessive boresight displacement seemed to have been largely solved by CDC. Although not conclusive, observations collected at this trial indicated that boresight retention of the sight was within both acceptance criteria, with only one value in excess of one milliradian.

THE SECOND PETE TRIAL

22. In order to provide essential data on the performance of Carl Gustav 84 mm ammunition at cold temperatures, it was decided to perform a series of live firings at PETE in February 1997. These firings would again be from a fixed mount at 700 metres range and would involve three ammunition temperatures : -10, -20, and -30 C. In order to ensure that no data would be lost due to ground impacts, DLR contracted with PETE to construct a new target which would be 24 feet tall. This target was used successfully in all further PETE trials on this project. It was also decided to take the opportunity to measure boresight displacement after each firing although the CLASS sight was not used for aiming at this trial.

23. The February 97 PETE trial was a success in several ways. The required cold temperature data for the ammunition was gathered, thus allowing CDC to develop the required modifications to the CLASS algorithm. The impact data collected also enabled DND to develop a modified acceptance criterion for system accuracy which would be achievable given the limitations imposed by the ammunition. Cooperation and trust between the parties was enhanced, characterized by an emphasis on finding a mutually acceptable solution to accuracy problems. The only glitch in the February 97 PETE trial was due to the weather, with a whole day lost when a snowstorm reduced visibility to the point where live firings were no longer safe.

24. The February 97 PETE trial also provided valuable data on the problem of boresight retention. Combined with data from the October 96 trial, there was sufficient data to allow the conclusion that CLASS boresight retention was now within acceptable limits. A memorandum detailing the analysis and conclusion was written to DLR on 26 Feb 97 and is shown in Figures 7(1) to 7(6) below.

Memorandum

ORA 3563-41302-1 (DGOR/CORT)

26 Feb 97

DLR 5-7 Attention Captain R. Hart

BORESIGHT RETENTION PERFORMANCE OF CLASS SIGHT

1. Two sets of test firings of the Carl Gustav 84mm weapon were conducted at PETE in Nicolet to provide additional information required for acceptance of the CLASS sight. In October 1996, 22 rounds were fired. In February 1997, another 46 rounds were fired. After each of these 68 rounds, a measurement of the boresight displacement of the CLASS sight was taken. The measurement procedure consisted of boresighting the CLASS sight before each round was fired and afterwards measuring boresight displacement by estimating the position of the sight crosshairs on a calibrated target. The target range for all 68 rounds was 700 metres.

2. Annex A contains a listing of the CLASS boresight displacement measurements for all 68 rounds. Displacements have been converted to milliradians. For the October firings, only one gun was used along with three different CLASS sights. For the February firings, three different guns as well as three different sights were used in a (nearly) balanced design. A total of 12 gun/sight combinations were measured in the course of the 68 firings. Under the assumption that the four guns and six sights were representative of their respective populations, it is considered that the 68 firings provide a good sample for the purpose of evaluating CLASS boresight retention. It must be noted however that the firings were conducted under ideal conditions with both DND and CDC providing technical experts to supervise the trials. In addition, it should be noted that since the CLASS sights were reboresighted before each round, no information on the possibility of cumulative sight displacement was obtained. Annex B contains detailed information on mean displacements by gun and sight as well as the results of a statistical analysis.

3. Two separate acceptance criteria exist for CLASS boresight retention. The first criterion is based on the critical region for a test of hypothesis that the probability of a boresight displacement in excess of 1 milliradian is at most 0.05. The significance level to be used is 0.05 and a binomial model is assumed. For a sample of 68 observations, the critical region is 7 or more observations in excess of 1 milliradian. Since only 4 of the 68 observations exceeded 1 milliradian, we conclude that there is not sufficient evidence to reject the null hypothesis and therefore that the CLASS sight has passed the first acceptance criterion in the PETE trials.

FIGURE 7(1) MEMORANDUM OF 26 FEB 97

4. The second acceptance criterion is that the mean sight displacement plus 1.645 times the standard deviation must not exceed 1.2 milliradians. For the 68 observations the mean sight displacement was 0.348 milliradians and the standard deviation was 0.461 milliradians, giving a value for the second acceptance criterion of 1.106 milliradians. Since this value is less than 1.2 milliradians, we conclude that the CLASS sight has passed the second acceptance criterion in the PETE trials.

5. It should be noted that the CLASS sight performance on boresight retention was within acceptance criteria limits despite the two large displacements in serials C06 and C07. The 3.147 milliradian value of C06 in particular is anomalous and may have been caused by improper sight mounting as noted in Annex A. The data were re-analyzed omitting serial C06. The mean displacement for the remaining 67 observations was 0.306 milliradians with a standard deviation of 0.309 milliradians. The value for purposes of the second acceptance criterion is 0.814 milliradians, a large improvement over the 1.106 milliradians which resulted when serial C06 was retained. For purposes of calculating system error budget contribution due to sight misalignment after one round has been fired, an estimate for sigma of 0.31 milliradians was derived from the 67 observations.

6. In summary, the CLASS sight performance in the October 1996 and February 1997 PETE trials was within acceptance criteria limits. Since 12 gun/sight combinations were used, it is considered that the 68 measurements provide a valid sample for acceptance test purposes. It must be noted however that measurements were conducted under ideal conditions and that no information was obtained on cumulative sight displacement.

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FIGURE 7(2) MEMORANDUM OF 26 FEB 97

Annex A

CLASS SIGHT DISPLACEMENT DATA FOR PETE TRIALS

OCTOBER 1996 DATA

Serial	Sight	Gun	Displacement (milliradians)	
W-1	41	00	0.000	(1)
W-2	41	00	0.000	(1)
B-1	41	00	0.135	
B-2	41	00	1.212	
B-3	41	00	0.183	
B-4	41	00	0.146	
B-5	41	00	0.132	
S-1	43	00	0.183	
S-2	43	00	0.706	
S-3	43	00	0.091	
S-4	43	00	0.202	
S-5	43	00	0.000	
B-6	40	00	0.000	
B-7	40	00	0.000	
B-8	40	00	0.000	
B-9	40	00	0.186	
B-10	40	00	0.000	
S-6	40	00	0.954	
S-7	40	00	0.714	
S-8	40	00	0.243	
S-9	40	00	0.114	
S-10	40	00	0.000	

(1) Sight displacement was not measured for serials W-1 and W-2 but in both cases the displacement was estimated to be nearly zero.

FIGURE 7(3) MEMORANDUM OF 26 FEB 97

FEBRUARY 1997 DATA

Serial	Sight	Gun	Displacement (milliradians)	
A01	20	01	0.236	
A02	20	01	0.176	
A03	20	01	0.589	
A04	20	01	0.647	
A05	20	01	0.529	
A06	20	01	0.647	(2)
A07	34	01	0.501	
A08	34	01	0.000	
A09	34	01	0.000	
A10	34	01	0.284	
A11	34	01	0.284	
A12	24	01	0.294	
A13	24	01	0.000	
A14	24	01	0.294	
A15	24	01	0.554	
A16	24	01	0.000	
A17	24	01	0.411	
B01	20	02	0.332	
B02	20	02	0.372	
B03	20	02	0.653	
B04	20	02	0.000	
B05	20	02	0.433	
B06	24	02	0.539	
B07	24	02	0.496	
B08	24	02	0.539	
B09	24	02	0.256	
B10	24	02	0.449	
B11	34	02	0.303	
B12	34	02	0.335	
B13	34	02	0.000	
B14	34	02	0.332	
B15	34	02	0.000	
C01	24	03	1.108	
C02	24	03	0.000	
C03	24	03	0.000	
C04	24	03	0.000	
C05	24	03	0.372	

FIGURE 7(4) MEMORANDUM OF 26 FEB 97

Serial	Sight	Gun	Displacement (milliradians)
C06	20	03	3.147 (2) (3)
C07	20	03	1.103 (3)
C08	20	03	0.449
C09	20	03	0.000
C10	20	03	0.000
C11	34	03	0.000
C12	34	03	0.320
C13	34	03	0.920
C14	34	03	0.539

(2) Displacement for serial A06 was corrected in azimuth by 1 milliradian because the sight was zeroed before the azimuth setting was applied. Displacement for serial C06 was corrected in azimuth by 0.5 milliradian for the same reason.

(3) Mr. Steve Marr of DASPM reported that the Class sight may have been improperly mounted for serials C06 and C07.

FIGURE 7(5) MEMORANDUM OF 26 FEB 97

Annex B

DETAILED ANALYSIS OF CLASS BORESIGHT DISPLACEMENT DATA

1. The SAS General Linear Models Procedure was applied to the boresight displacement data of Annex A. No significant effects were found for the four guns, the six sights, or any gun/sight interactions.

Number of displacement values = 68

Mean displacement = 0.348 milliradians

Standard deviation = 0.461 milliradians

Gun Number	N	Mean	St. Deviation
00	22	0.236	0.341
01	17	0.320	0.233
02	15	0.336	0.203
03	14	0.568	0.851

Sight Number	N	Mean	St. Deviation
20	16	0.582	0.745
24	16	0.332	0.299
34	14	0.273	0.267
40	10	0.221	0.340
41	7	0.258	0.427
43	5	0.236	0.274

FIGURE 7(6) MEMORANDUM OF 26 FEB 97

THE ISSUE OF ACHIEVABLE ACCURACY

25. With the problem of round to round boresight retention having been solved, the remaining issue was what to do about the accuracy problems associated with ground impacts at low ammunition temperature. As a first step in this direction, a memorandum outlining the problem dated 18 MAR 97 was sent to DLR. See Figures 8(1) to 8(3) below. This memorandum was written after a thorough analysis of impact data from the February 97 trial and concluded that the goal of an eighty percent hit probability at 700 metres was not achievable given the observed ammunition variability at low temperatures. A revised value of seventy percent was recommended.

26. There are important lessons to be noted from the 18 MAR 97 memorandum and subsequent decisions. With respect to the initial contract and the specification of a hit probability of 0.80 on a 2.3 metre square target at 700 metres, it is clear that CDC and to some extent DND, made a mistake incorporating an unachievable goal in a legal contract. CDC in particular found themselves in a difficult position when it became clear that the limiting factor on achievable accuracy was the ammunition, a matter over which CDC had no control. For DND, the issue was whether the eighty percent hit probability was crucial in deciding to acquire the CLASS sight, or whether a lower value was acceptable. In this respect, the importance of a careful and unbiased analysis of actual performance data becomes obvious.

Memorandum

ORA 3563-41302-1 (DGOR/CORT)

18 Mar 97

DLR 5-7 Attention Capt. R. Hart

HIT PROBABILITY CONSIDERATIONS FOR CARL GUSTAV WITH CLASS SIGHT

1. As a result of test firings at PETE in February, 1997, we are now in a position to begin planning of acceptance trials and suitable acceptance criteria for the Carl Gustav 84mm weapon equipped with the CLASS sight. There are two essential points which must be dealt with : the problem of determining the proper aiming elevation in order to ensure that the mean vertical impact point is at target centre; and given this, the calculation of expected hit probability as a function of impact dispersion.

2. From detailed data collected during live firings at Gagetown and more recently at PETE, it appears that some quadrant elevation values provided by the Bofors range tables are low by a significant amount. This problem was particularly evident at 700 m. target range and low ammunition temperatures, resulting in consistent vertical impact deviations below target centre and several ground impacts. Analysis of data from the February PETE trial indicates that the correction is of the order of 1 to 1.5 mils or more at 700 metres range, depending on the ammunition temperature. A change in quadrant elevation of this magnitude corresponds to an impact height change of around 1 metre. It seems clear at this point that a correction will have to be added to the quadrant elevation given by the Bofors range table when firing at long range and cold temperatures. The CLASS sight computer algorithm would also have to be appropriately modified. Determination of the proper corrections and subsequent implementation and testing would necessarily involve CDC. Without these corrections, the expected performance enhancement at longer ranges due to the CLASS sight on the Carl Gustav weapon will not be achievable.

3. Assuming that the CLASS sight algorithm can be modified to provide quadrant elevations for long range and low temperatures which result in a mean vertical impact point at target centre, it remains to determine conditions and criteria for an acceptance trial of hit probability performance. The contract between DND and CDC specifies a hit probability of 0.8 for a 2.3 metre square target at 700 metres range, exclusive of operator aiming error. While it may be feasible to achieve such a hit probability with the Carl Gustav / CLASS sight combination at proofing temperatures of

FIGURE 8(1) MEMORANDUM OF 18 MAR 97

21 C, this is not the case at colder temperatures. Experience at the two PETE trials indicates that the dispersion of the Carl Gustav rounds increases materially at cold temperatures, to the point that it may be physically impossible to achieve a hit probability of 0.8 for the 2.3 metre target at 700 metres due solely to inherent round to round variability. Based on a detailed analysis of data from the February PETE trial, a more feasible hit probability which takes into account the increased dispersion at cold temperatures is 0.7 . .

4. It is recommended that an acceptance trial of the Carl Gustav / CLASS sight system for hit probability be conducted at PETE using the same firing setup as in the February 1997 trials, at a range of 700 metres. Each round would be aimed using the CLASS sight with current meteorological data. As in the October 1996 and February 1997 trials, boresight displacement should be recorded after each firing but in this case no correction will be made so that cumulative boresight displacement can be observed. As a preliminary planning figure, a total of 30 rounds is recommended, with at least three ammunition temperature values ranging from 0 C to -30 C. It is recommended that 10 rounds be fired at each temperature and that three different guns and sights be employed so that each independent gun / sight combination is used for 10 rounds.

5. As discussed above, it is recommended that the nominal hit probability used for determining the acceptance criterion be lowered from 0.8 to 0.7 due to the fact that low ammunition temperatures will be used. For 30 rounds and a probability of hit of 0.7, the expected number of hits is 21. The following table gives the cumulative probability for the number of hits for 30 rounds and a hit probability of 0.7. The cumulative probability values enable the calculation of 'producer's risk', ie. the probability of not accepting when in fact the hit probability is 0.7.

Number of Hits	Cumulative Probability
15	0.02
16	0.04
17	0.08
18	0.16
19	0.27
20	0.41
21	0.57
22	0.72

FIGURE 8(2) MEMORANDUM OF 18 MAR 97

6. It is recommended that the acceptance criterion for the number of hits on the 2.3 metre square target be set at 18. Given that the actual hit probability is 0.7, it can be seen from the table that the producer's risk is 0.08. In other words, the probability of failing to achieve at least 18 hits out of 30 is 0.08 when hit probability is 0.7 This level of risk is consistent with normal statistical practice.

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FIGURE 8(3) MEMORANDUM OF 18 MAR 97

ADDITIONAL FIRINGS AT PETE IN JULY 1997

27. After the successful trial of February 1997, a series of meetings followed during which it was agreed that CDC would modify the CLASS sight algorithm for medium range and low ammunition temperature in accordance with the data collected. DND agreed to plan an acceptance trial at PETE for late summer or early fall in which the accuracy requirement would be for a hit probability of 0.70 overall, with four ammunition temperatures and two target ranges being used.

28. In order to enable CDC to modify the CLASS sight algorithm, an additional series of test firings was scheduled at PETE for July 1997. Six rounds were fired at a target range of 500 metres for each of three ammunition temperatures: 0, 10, and 21 C. This trial was carried out with no unusual difficulties on July 23, 1997.

29. Following the July 1997 firings at PETE, there was sufficient data across ammunition temperatures ranging from 21 C to -40 C to allow CDC to incorporate corrections to the Bofors firing tables for the Carl Gustav 84 mm HEAT (551) round. Note however that only SNC-produced rounds from lot CA-87H02-04 had been used in all the test firings to date. The decision was made to use only rounds from this lot in order to enable a solution to the impasse over acceptance of the CLASS sight. It was decided to postpone the examination of lot to lot variability until after the CLASS sight issues had been resolved, incorporating this factor into a broad study of 84 mm ammunition variability and quality control.

PLANNING FOR THE FINAL CLASS SIGHT ACCEPTANCE TRIAL

30. The final acceptance trial for the CLASS sight was scheduled to be held at PETE on 23 to 25 September 1997. It was decided to fire 40 rounds, each aimed independently using the CLASS sight on a fixed mount with the latest meteorological data being entered for each round. The test plan called for three guns, three sights, four ammunition temperatures spanning the expected operational range, and target ranges of 500 and 700 metres. A fully randomized complete factorial experimental design was not possible due to practical constraints such as ammunition availability and the need to change the firing setup at the two target ranges, but a fair and comprehensive trial was designed with randomization of factors where possible.

31. As the planning for the September acceptance trial progressed, the issue of outliers became contentious. On the one hand, since the trial was about system accuracy, obvious malfunctions such as dud rounds or misfires should not be counted since they give no accuracy information. On the other hand, a round which is fully functional in all respects but which happens to miss the target by a margin of a small number of metres is not necessarily an outlier. After a series of attempts to come to grips with this issue, a detailed and complex analysis was performed in which dispersion data obtained over the earlier trials at ammunition temperatures bracketing the planned values was combined with previous theoretical work. The resulting outlier criterion was accepted by all parties, being soundly based on actual data and intrinsically fair. A memorandum dated 29 AUG 97 on this issue was written for DLR and is presented below in Figures 9(1) to 9(5).

32. The outlier memorandum of 29 AUG 97 was the product of a week of intensive effort. It required familiarity with the data gathered at previous trials, an understanding of the practicalities of actually carrying out the firings, a knowledge of the technical factors involved and a strong grasp of the theoretical issues. The two lessons that emerge are the need for the analyst to become familiar with the practical issues by personally attending the trials when possible and the importance of understanding the mathematical basis of statistical procedures.

Memorandum

3563-41302-1 (CORT)

29 Aug 97

Distr List

DETERMINATION OF OUTLIERS FOR CLASS/CARL GUSTAV ACCURACY TRIALS

Ref: Department of National Defence, Operational Research and Analysis, Directorate of Mathematics and Statistics Research Note 5/94 : Parameter Uncertainty in Range Safety Calculations by E. J. Emond, August 1994.

1. A series of forty test firings of the Carl Gustav 84mm weapon equipped with the CLASS sight is planned for late September 1997. The purpose of this trial is to assess system accuracy at medium ranges against a standard NATO target. Four different ammunition temperatures will be used, spanning the expected operational range. The trial will also employ three different CLASS sights and three different Carl Gustav guns. System accuracy will be evaluated at 500 and 700 metres target range. Due to practical considerations, a full factorial design is not possible; however, a balanced design has been created which will provide a fair and comprehensive test of system accuracy.

2. One of the practical considerations of this trial is the determination of outliers. This is a thorny issue because on the one hand we are interested in assessing system accuracy so that obvious malfunctions such as dud rounds or misfires should not be counted because they give no accuracy information. On the other hand, a round which is fully functional in all respects but which happens to miss the target by a margin of a small number of metres is not necessarily an outlier.

3. An approach based on the information recorded in earlier test firings at PETE in February and July 1997 has been developed. An outlier rectangle has been calculated based on the available data from earlier firings at temperatures which bracket the planned values. Details are presented in Annex A to this memorandum.

4. The data values consisted of the vertical and horizontal deviations from the respective mean points of impact for the test firings at those temperatures which bracket the planned values. A total of 58 data points have been included, with six values at 10 C, six values at 0 C, 17 values at -10 C, 15 values at -20 C, and 14 values at -30 C. A statistical test of hypothesis was performed on the combined data to test for equality of the vertical and horizontal variances. For the combined data, the vertical variation is significantly greater than the horizontal. Therefore it was decided that an assumption of circular Normality was not warranted and that a rectangular outlier area was indicated in accordance with pages 17-18 of Reference 1.

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FIGURE 9(1) MEMORANDUM OF 29 AUG 97

5. In order to calculate an outlier rectangle it is necessary to specify a P value. This value represents the theoretical probability of a round impacting beyond the outlier rectangle purely by chance. Possible P values are 0.01 (one in one hundred), 0.001 (one in one thousand), or 0.0001 (one in ten thousand). The middle value of 0.001 or one in one thousand was chosen for this analysis because it represents a reasonable compromise between the liberal value of 0.01 and the conservative value of 0.0001. The resulting outlier rectangle appears fair and reasonable when plotted with the actual data as shown in Annex 1.

6. For the combined 58 data points, the values of horizontal and vertical standard deviation have been estimated at 1.04 milliradians and 1.37 milliradians respectively. In accordance with Reference 1, the multiplier associated with a P value of 0.001 when 58 data values are available is 3.70.

7. The table below gives the calculated outlier rectangle half-widths for both the 500 metre and 700 metre ranges using the method outlined above.

OUTLIER RECTANGLE HALF WIDTHS

500 m. Outlier Rectangle		700 m. Outlier Rectangle	
Horizontal	Vertical	Horizontal	Vertical
1.92 m. by	2.53 m.	2.69 m. by	3.55 m.

8. It should be noted that the outlier rectangle given above defines 'automatic' outlier values in that a round which impacts beyond the given rectangle is automatically declared an outlier. In the event that evidence exists which indicates that a round has missed the target due to a mechanical malfunction, the round may be declared an outlier even if it impacts within the 'automatic' outlier rectangle.

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Attachment:
Annex A – Outlier Analysis

Distr List

DLR 5-7 – Captain R. Hart
DASPM 4-3-2 (C1) – Attn: Mr. Stephen Marr

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FIGURE 9(2) MEMORANDUM OF 29 AUG 97

ANNEX A
3563-41302-1 (CORT)
29 Aug 97

OUTLIER ANALYSIS

1. Although the ammunition temperatures to be used in the acceptance trials have not yet been specified, it is known that T1 will lie between 10 C and 0 C, T2 will lie between 0 C and -10 C, T3 will lie between -10 C and -20 C, and T4 will lie between -20 C and -30 C. A detailed analysis of the data collected at PETE in February and July 1997 for these temperatures indicates that it is reasonable to combine the miss distances (from mean point of impact) for the purpose of determining the outlier criterion. The relevant data are given below.

	Dataset ID	Miss Distances in milliradians (Measured from MPI)	
10 C	(JUL 97 B1)	-1.603	-0.227
10 C	(JUL 97 B2)	2.617	1.293
10 C	(JUL 97 B3)	-0.663	-0.427
10 C	(JUL 97 B4)	-0.503	-0.827
10 C	(JUL 97 B5)	-0.743	-0.507
10 C	(JUL 97 B6)	0.897	0.693
0 C	(JUL 97 A1)	-1.323	-3.180
0 C	(JUL 97 A2)	0.577	-0.720
0 C	(JUL 97 A3)	0.737	-0.640
0 C	(JUL 97 A4)	0.657	-0.040
0 C	(JUL 97 A5)	-1.223	2.160
0 C	(JUL 97 A6)	0.577	2.420
-10 C	(FEB 97 A1)	-0.764	-0.237
-10 C	(FEB 97 A2)	0.265	0.463
-10 C	(FEB 97 A3)	-0.264	-1.608
-10 C	(FEB 97 A4)	0.465	-0.851
-10 C	(FEB 97 A5)	0.822	-0.837
-10 C	(FEB 97 A6)	-1.364	-0.037
-10 C	(FEB 97 A7)	0.322	-0.366
-10 C	(FEB 97 A8)	0.136	-1.508
-10 C	(FEB 97 A9)	0.765	1.349
-10 C	(FEB 97 A10)	-1.207	0.649
-10 C	(FEB 97 A11)	0.193	0.406
-10 C	(FEB 97 A12)	-0.478	-0.380
-10 C	(FEB 97 A13)	2.265	0.220
-10 C	(FEB 97 A14)	-0.250	0.777
-10 C	(FEB 97 A15)	-0.864	0.120
-10 C	(FEB 97 A16)	0.565	1.249
-10 C	(FEB 97 A17)	-0.607	0.592
-20 C	(FEB 97 B1)	-0.023	2.448
-20 C	(FEB 97 B2)	0.406	-0.552

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FIGURE 9(3) MEMORANDUM OF 29 AUG 97

	Dataset ID	Miss Distances in milliradians (Measured from MPI)	
-20 C	(FEB 97 B3)	0.120	2.033
-20 C	(FEB 97 B4)	0.706	-0.324
-20 C	(FEB 97 B5)	-0.137	-1.295
-20 C	(FEB 97 B6)	-0.109	0.305
-20 C	(FEB 97 B7)	0.906	1.733
-20 C	(FEB 97 B8)	-1.251	-0.738
-20 C	(FEB 97 B9)	-0.780	0.548
-20 C	(FEB 97 B10)	1.791	-3.781
-20 C	(FEB 97 B11)	0.491	-0.981
-20 C	(FEB 97 B12)	-1.451	0.276
-20 C	(FEB 97 B13)	-1.309	-1.667
-20 C	(FEB 97 B14)	0.149	0.248
-20 C	(FEB 97 B15)	0.491	1.748
-30 C	(FEB 97 C1)	1.637	3.314
-30 C	(FEB 97 C2)	-0.563	-0.514
-30 C	(FEB 97 C3)	-0.935	1.357
-30 C	(FEB 97 C4)	-2.106	-0.371
-30 C	(FEB 97 C5)	-0.106	-3.200
-30 C	(FEB 97 C6)	-0.749	0.743
-30 C	(FEB 97 C7)	-0.320	1.229
-30 C	(FEB 97 C8)	-1.406	-1.214
-30 C	(FEB 97 C9)	1.594	0.086
-30 C	(FEB 97 C10)	-0.920	-1.386
-30 C	(FEB 97 C11)	-0.063	-0.786
-30 C	(FEB 97 C12)	0.351	0.843
-30 C	(FEB 97 C13)	2.322	0.986
-30 C	(FEB 97 C14)	1.265	-1.086

2. The estimated horizontal and vertical standard deviations for these 58 data points are 1.04 and 1.37 milliradians respectively. In accordance with page 18 of DMS Research Note 5/94 and using a P value of 0.001, with 58 data values we require a multiplier of 3.70 in order to estimate the outlier rectangle. In this case we get a value of 3.85 milliradians for the horizontal half width of the outlier rectangle and a value of 5.07 milliradians for the vertical. These values may be converted to metres at the two planned ranges as shown below.

Range	Rectangle Half Widths	
	Horizontal	Vertical
500 metres	1.92 metres	2.53 metres
700 metres	2.69 metres	3.55 metres

A-2

FIGURE 9(4) MEMORANDUM OF 29 AUG 97

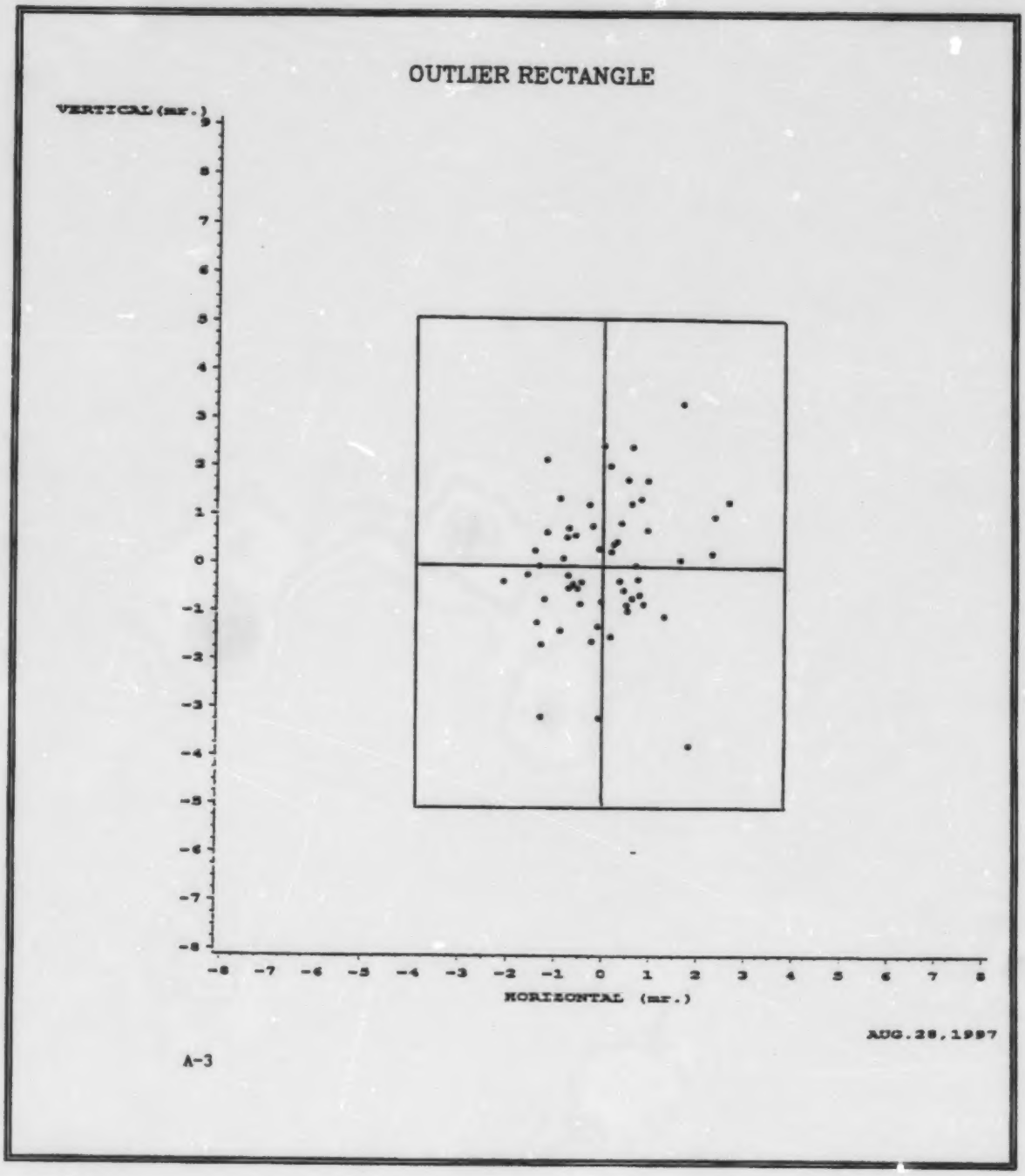

FIGURE 9(5) MEMORANDUM OF 29 AUG 97

FINAL ACCEPTANCE TRIAL OF SEPTEMBER 1997

33. The final CLASS sight acceptance trial for accuracy was held at PETE on September 23 to 25 1997. In attendance were representatives from CDC as well as DLR, DASPM, and the DGOR analyst. The trial started disastrously when three of the first seven rounds failed to hit the 12 by 24 foot target and the other four displayed a severe horizontal bias to the right of centre. A decision was made to halt the trial after these seven rounds in order to allow time to think about what might be causing this unexpected problem. Several theories were advanced, particularly with regard to the strong crosswinds encountered during the firings. The CDC consultant came up with the solution when he suggested a procedure to check the vertical alignment of the CLASS sight on its mounting. It was discovered that the CLASS sight had been mounted improperly, resulting in an aim point bias when the gun was elevated to the necessary firing angle.

34. It was decided to discount the results of the September 23 firings and to continue the acceptance trial starting at round four. Four additional rounds were added after round 28 using spare rounds in order to make up for missing rounds 1 to 3 as well as round 9 which was declared an outlier due to mechanical failure. The existence of the necessary spare rounds was due to the foresight of CWO Deroy of PETE who has long experience in the running of trials. The final 12 rounds were fired on September 25 after the firing point had been moved to 500 metres. Several hours delay was experienced on this day due to the removal of duck hunters in the swampy areas behind the firing point.

35. A detailed memorandum on the September 1997 acceptance trial was written. This memorandum was dated 14 OCT 97 and is presented in Figures 10(1) to 10(14) below. Although the nominal acceptance criterion of seventy percent was not achieved, the detailed analysis indicated that the CLASS sight was performing as expected and giving a centre of impact which was not significantly different from target centre at the 700 metre range. Results at 500 metres were mixed, but there was no evidence of previous problems with low vertical impact points. Failure to achieve the seventy percent hit probability was judged to be due to ammunition variability. It was therefore decided by DND to accept the results as indicating that the CLASS sight was performing adequately with respect to accuracy at short range. No problems with round to round or cumulative boresight displacement were observed.

Memorandum

3563-41302-1 (CORT)

14 Oct 97

DLR 5-7 - Captain R. Hart

ANALYSIS OF ACCEPTANCE TRIAL DATA FOR CLASS / CARL GUSTAV SYSTEM

Reference : Test Report, 84 mm CARL GUSTAF, CLASS SIGHT HIT PROBABILITY ACCEPTANCE TEST, Firing Data; Proof and Experimental Test Establishment, Nicolet; Sep. 29, 1997.

1. The acceptance trial for system accuracy for the Carl Gustav 84 mm weapon with the CLASS sight was conducted at PETE on September 23 to 25, 1997. The trial plan called for a series of forty rounds plus warmers and included four ammunition temperatures; two target ranges, three different guns and three CLASS sights. All shots were fired from a fixed mount to eliminate operator aiming error and in each case the CLASS sight was used to determine the aim point given the target range, ammunition temperature and meteorological conditions. In addition to personnel from PETE, the trial was attended by Captain Hart, Mr. Marr and Mr. Emond of NDHQ and two representatives of Computing Devices of Canada.

2. Due to technical problems which resulted in the improper setup of the CLASS sight, the results of the first 5 shots, all fired on the afternoon of September 23, were discounted for purposes of the accuracy acceptance trial. The problem was corrected on the morning of September 24 and rounds number 6 through 28 were successfully fired following the trial plan. The results from round number 9 were discounted due to observed erratic trajectory and the presence of debris. It was decided to fire four spare rounds with the same setup as round 28 (700 m., Sight 3, Gun 3) in order to achieve the planned number of rounds at the 700 metre target range. The rounds were designated as follows : Round 29a (ammunition temperature -14C), Round 29b (ammunition temperature -3C), Round 28c (ammunition temperature -26C), and Round 28d (ammunition temperature -26C).

3. The number of valid shots achieved at the 700 metre target range was 28, equalling the number in the trial plan. Annex A to this memorandum gives details of the impact points observed including a diagram. The mean horizontal and vertical impact

FIGURE 10(1) MEMORANDUM OF 14 OCT 97

points were not significantly different from the target centre, indicating in particular that previous vertical bias problems at this range which resulted in numerous ground impacts have now been corrected. In addition, statistical analysis indicates that both the horizontal and vertical standard deviations for the acceptance trial rounds were not significantly different from values observed in previous firings.

4. The acceptance trial accuracy standard is a 2.3 metre square standard NATO target. Seventeen of the twenty eight rounds at the 700 metre target range impacted within the 2.3 metre square for a hit proportion of 61 percent. This proportion is consistent with predictions based on earlier firings and is about the best that can be achieved given the observed and consistently high vertical standard deviation of the Carl Gustav weapon at these conditions. Note that the centroid of the impact points is approximately at the target centre indicating that the sight system is performing properly and that any increase in hit probability would require that the dispersion of the weapon be reduced.

5. The firing point was moved to the 500 metre target range position on the afternoon of September 24. Rounds 29 to 31 were successfully fired and in order to save time rounds 35 to 37 were fired next. Rounds 32 to 34 and 38 to 40 were fired on the morning of September 25. Results from round 38 were discounted due to observed erratic trajectory. Thus a total of 11 observations was achieved for the 500 metre target range, one less than the planned value. Annex B to this memorandum gives the impact point details for the 11 rounds fired at 500 metre target range including a diagram.

6. Statistical analysis indicates that the mean vertical impact point for the 11 rounds was not significantly different from zero. This again indicates that previous problems with vertical bias were not present in the acceptance trials. However, the mean horizontal impact point for the 11 rounds was significantly to the left of target centre as indicated by a t test at the 5 percent significance level. In addition, while the horizontal standard deviation observed in the acceptance trial was consistent with previous firings, the vertical standard deviation was significantly greater than that observed in previous firings. The reason for these findings is not known.

7. Given the bias in the impact points to the left of target centre and the very large vertical dispersion observed, it is not surprising that only 6 of the 11 rounds impacted within the standard 2.3 metre target. The observed proportion, 55 percent, is lower that the expected 80 percent indicated by previous firings but is consistent with the observed large vertical dispersion of the rounds. The fact that the vertical mean point of impact was

FIGURE 10(2) MEMORANDUM OF 14 OCT 97

not significantly different from zero indicates that the CLASS system was performing properly with respect to elevation. The presence of a significant impact point bias left of target centre indicates that the aim point was not correct in terms of azimuth. The reason for this is not known, although the presence of strong gusting winds may have contributed.

SIGHT DISPLACEMENT OBSERVATIONS

8. After each firing the resulting sight displacement was measured in order to verify that previous problems have in fact been corrected. Although several CLASS boresight displacement observations of approximately 0.5 milliradian were recorded, there was no case in which the sight displacement was of any practical significance and no cumulative displacement was observed.

SUMMARY AND CONCLUSIONS

9. The acceptance trial as planned and carried out constitutes a fair and valid test of the accuracy of the Carl Gustav / CLASS system at medium target ranges. Results from the 700 metre range indicate that the system was functioning properly in placing the mean impact point of the rounds at target centre. The proportion of hits on the standard 2.3 metre target was 61 percent, consistent with expectations based on previous firings. At the 500 metre range the mean point of impact was significantly left of target centre and the vertical dispersion of the rounds was significantly higher than in previous trials. Observed hit proportion was only 55 percent. The overall hit proportion for the 39 rounds of this acceptance trial was 59 percent, well short of the nominal 70 percent agreed upon for acceptance purposes.

10. Results at 700 metres indicate that modifications to the aiming algorithm made by CDC and based on earlier test firings have been successful in correcting the ground impact problem. Analysis of the dispersion of the impact points indicates that further changes to the CLASS sight would not result in a higher hit probability because the limiting factor at present is the large vertical dispersion of the rounds themselves. Results at 500 metres are more puzzling although no problem was observed with respect to mean vertical impact point. The main reason for the poor hit proportion at 500 metres is undoubtedly the anomalously high vertical dispersion of the rounds. This again leads to the conclusion that further changes to the CLASS sight would not necessarily increase hit probability because the limiting factor appears to be high vertical dispersion associated with the Carl Gustav rounds themselves.

FIGURE 10(3) MEMORANDUM OF 14 OCT 97

11. It is concluded that ground impact and sight displacement problems observed in earlier trials with the Carl Gustav/CLASS system did not recur in the September acceptance trial. The acceptance trial showed no evidence of vertical bias or significant sight displacement. Although hit proportions were lower than the nominal 70 percent agreed upon as the acceptance criterion, it is our opinion that improvements to the 59 percent hit proportion recorded in this trial are not achievable by modifications to the CLASS sight and will have to be based on reducing the vertical dispersion of the rounds themselves.

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Attachments:
Annex A - Results From 700 Metre Firings
Annex B - Results From 500 Metre Firings

FIGURE 10(4) MEMORANDUM OF 14 OCT 97

ANNEX A : RESULTS FROM 700 METRE FIRINGS

ROUND NUMBER	HORIZONTAL IMPACT POINT (Metres)	VERTICAL IMPACT POINT (Metres)
4b	0.18	0.10
5	-0.42	-1.59
6	-1.36	0.66
7	-1.69	1.63
8	0.16	0.71
10	-0.97	-0.23
11	-0.25	-1.44
12	-0.01	0.77
13	-0.24	-1.81
14	-0.04	1.02
15	-0.29	-0.76
16	-0.23	-0.09
17	0.03	1.15
18	0.87	-2.37
19	-0.03	0.49
20	0.70	0.48
21	1.11	-0.63
22	0.82	0.59
23	-1.00	-0.11
24	-0.31	-1.48
25	-0.62	-0.96
26	-0.18	-0.06
27	-0.75	1.61
28	-0.46	2.14
28a	0.21	1.32
28b	-0.93	0.09
28c	0.29	2.27
28d	-0.56	0.08

Mean Horizontal Impact Point = -0.21 metres

Mean Vertical Impact Point = 0.13 metres

Horizontal Standard Deviation = 0.66 metres

Vertical Standard Deviation = 1.20 metres

FIGURE 10(5) MEMORANDUM OF 14 OCT 97

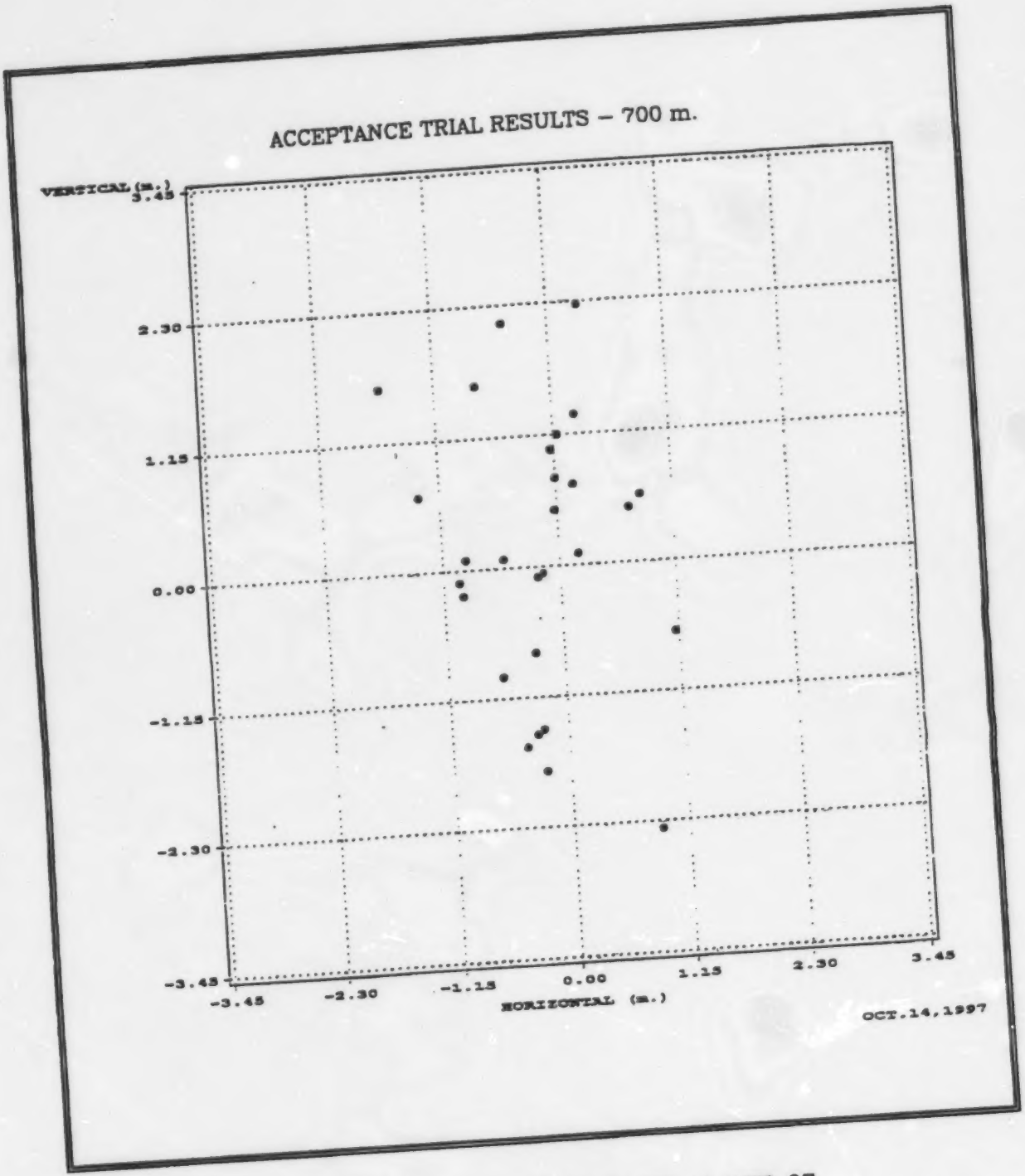

FIGURE 10(6) MEMORANDUM OF 14 OCT 97

1. Mean Horizontal Impact Point

Null Hypothesis: Mean Horizontal Impact Point at Zero

Sample size: n = 28

Mean value: xbar = -0.213 metres

Sample standard deviation: s(x) = 0.656 metres

Critical Region : xbar greater than 2.052 * s(x) / sqrt(28)

or : xbar less than -2.052 * s(x) / sqrt(28)

(T test with two sided 95 percent level of confidence.

In this case the critical region is xbar greater than plus or minus 0.254 metres.

Therefore we cannot reject the null hypothesis. We conclude that the mean horizontal impact point for these 28 rounds was not significantly different from zero at the 95 percent level of confidence.

2. Mean Vertical Impact Point

Null Hypothesis: Mean Vertical Impact Point at Zero

Sample size: n = 28

Mean value: ybar = 0.128 metres

Sample standard deviation: s(y) = 1.197 metres

Critical Region : ybar greater than 2.052 * s(y) / sqrt(28)

or : ybar less than -2.052 * s(y) / sqrt(28)

(T test with two sided 95 percent level of confidence.

In this case the critical region is ybar greater than plus or minus 0.464 metres.

FIGURE 10(7) MEMORANDUM OF 14 OCT 97

Therefore we cannot reject the null hypothesis. We conclude that the mean vertical impact point for these 28 rounds was not significantly different from zero at the 95 percent level of confidence.

3. Horizontal Standard Deviation

Null hypothesis: Horizontal Standard Deviation same as previous firings.

Number of rounds = 28

Observed horizontal standard deviation = s1 = 0.656 metres

Data from previous firings at similar ammunition temperatures :

Number of rounds = 58

Observed horizontal standard dev. = 1.04 milliradians

Horizontal standard dev. at 700 metres = s2 = 0.73 metres

Critical Region :

Reject null hypothesis if (s1/s2)**2 greater than 1.88

Reject null hypothesis if (s2/s1)**2 greater than 2.01

(F test with two sided 95 percent level of confidence.)

Value of (s1/s2)**2 = 0.81

Value of (s2/s1)**2 = 1.24

Therefore we cannot reject the null hypothesis. We conclude that the horizontal standard deviation for these 28 rounds was not significantly different from that observed for the previous rounds at the 95 percent level of confidence.

4. Vertical Standard Deviation

Null hypothesis: Vertical Standard Deviation same as previous firings.

FIGURE 10(8) MEMORANDUM OF 14 OCT 97

Number of rounds = 28

Observed vertical standard deviation = s1 = 1.197 metres

Data from previous firings at similar ammunition temperatures :

Number of rounds = 58

Observed vertical standard dev. = 1.37 milliradians

Vertical standard dev. at 700 metres = s2 = 0.96 metres

Critical Region :

Reject null hypothesis if (s1/s2)**2 greater than 1.88

Reject null hypothesis if (s2/s1)**2 greater than 2.01

(F test with two sided 95 percent level of confidence.)

Value of (s1/s2)**2 = 1.55

Value of (s2/s1)**2 = 0.64

Therefore we cannot reject the null hypothesis. We conclude that the vertical standard deviation for these 28 rounds was not significantly different from that observed for the previous rounds at the 95 percent level of confidence.

FIGURE 10(9) MEMORANDUM OF 14 OCT 97

ANNEX B : RESULTS FROM 500 METRE FIRINGS

ROUND NUMBER	HORIZONTAL IMPACT POINT (Metres)	VERTICAL IMPACT POINT (Metres)
29	-0.35	0.86
30	-0.48	-0.33
31	-1.19	-1.64
35	-0.30	1.54
36	-0.63	-0.33
37	0.47	0.64
32	-1.58	1.22
33	-0.90	1.71
34	-0.21	0.08
39	-0.78	0.39
40	-0.01	2.00

Mean Horizontal Impact Point = -0.54 metres

Mean Vertical Impact Point = 0.56 metres

Horizontal Standard Deviation = 0.57 metres

Vertical Standard Deviation = 1.08 metres

FIGURE 10(10) MEMORANDUM OF 14 OCT 97

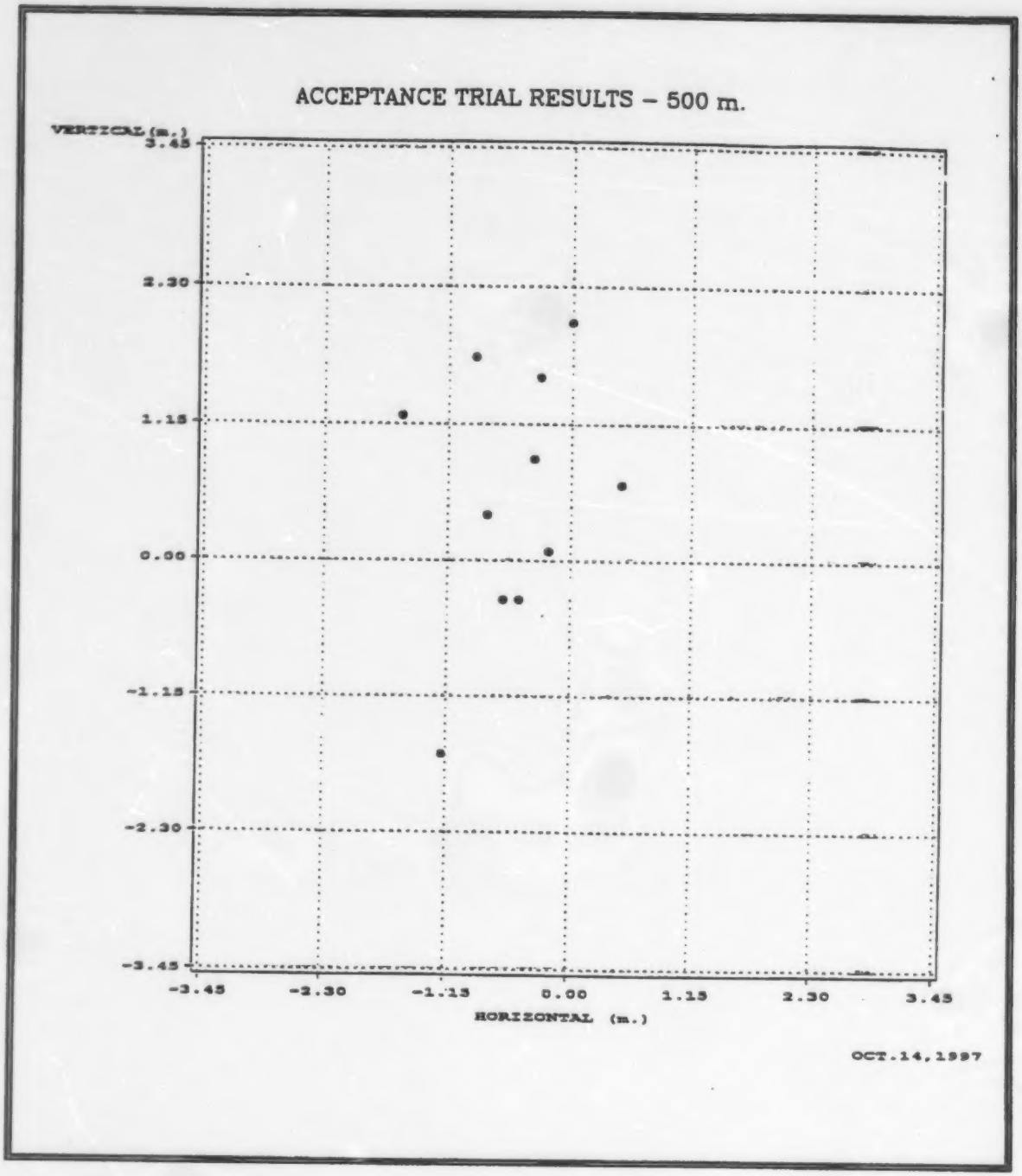

FIGURE 10(11) MEMORANDUM OF 14 OCT 97

1. Mean Horizontal Impact Point

Null Hypothesis: Mean Horizontal Impact Point at Zero

Sample size: n = 11

Mean value: xbar = -0.542 metres

Sample standard deviation: s(x) = 0.566 metres

Critical Region : xbar greater than 2.228 * s(x) / sqrt(11)

or : xbar less than -2.228 * s(x) / sqrt(11)

(T test with two sided 95 percent level of confidence.

In this case the critical region is xbar greater than plus or minus 0.38 metres.

Therefore we reject the null hypothesis. We conclude that the mean horizontal impact point for these 11 rounds was significantly different from zero at the 95 percent level of confidence.

2. Mean Vertical Impact Point

Null Hypothesis: Mean Vertical Impact Point at Zero

Sample size: n = 11

Mean value: ybar = 0.558 metres

Sample standard deviation: s(y) = 1.076 metres

Critical Region : ybar greater than 2.228 * s(y) / sqrt(11)

or : ybar less than -2.228 * s(y) / sqrt(11)

(T test with two sided 95 percent level of confidence.

In this case the critical region is ybar greater than plus or minus 0.72 metres.

FIGURE 10(12) MEMORANDUM OF 14 OCT 97

Therefore we cannot reject the null hypothesis. We conclude that the mean vertical impact point for these 11 rounds was not significantly different from zero at the 95 percent level of confidence.

3. Horizontal Standard Deviation

Null hypothesis: Horizontal Standard Deviation same as previous firings.

Number of rounds = 11

Observed horizontal standard deviation = s1 = 0.566 metres

Data from previous firings at similar ammunition temperatures :

Number of rounds = 58

Observed horizontal standard dev. = 1.04 milliradians

Horizontal standard dev. at 500 metres = s2 = 0.52 metres

Critical Region :

Reject null hypothesis if (s1/s2)**2 greater than 2.31

Reject null hypothesis if (s2/s1)**2 greater than 3.21

(F test with two sided 95 percent level of confidence.)

Value of (s1/s2)**2 = 1.18

Value of (s2/s1)**2 = 0.84

Therefore we cannot reject the null hypothesis. We conclude that the horizontal standard deviation for these 11 rounds was not significantly different from that observed for the previous rounds at the 95 percent level of confidence.

4. Vertical Standard Deviation

Null hypothesis: Vertical Standard Deviation same as previous firings.

FIGURE 10(13) MEMORANDUM OF 14 OCT 97

Number of rounds = 11

Observed vertical standard deviation = s1 = 1.076 metres

Data from previous firings at similar ammunition temperatures :

Number of rounds = 58

Observed vertical standard dev. = 1.37 milliradians

Vertical standard dev. at 500 metres = s2 = 0.69 metres

Critical Region :

Reject null hypothesis if (s1/s2)**2 greater than 2.31

Reject null hypothesis if (s2/s1)**2 greater than 3.21

(F test with two sided 95 percent level of confidence.)

Value of (s1/s2)**2 = 2.43

Value of (s2/s1)**2 = 0.41

Therefore we reject the null hypothesis. We conclude that the vertical standard deviation for these 11 rounds was significantly greater than that observed for the previous rounds at the 95 percent level of confidence.

FIGURE 10(14) MEMORANDUM OF 14 OCT 97

LESSONS LEARNED FROM THE SEPTEMBER 1997 TRIAL

36. The value of having all the key players in attendance at the acceptance trial was underscored by the quick and correct decision to halt the firings after the first seven rounds. In addition, the early discovery of the cause of the horizontal bias problem was due to the presence of the CDC analyst. The statistical validity of the procedures adopted to cope with the loss of data in the first few firings was maintained due to the presence of the DGOR analyst who was acting as statistical consultant.

37. Once again, the importance of flexibility and the foresight which comes from experience as displayed by the PETE trials staff were made evident in this trial. The value of randomization to negate the effects of uncontrollable variability in trial conditions is evidenced by this trial as well, where winds varied considerably over the three days and procedures evolved to adapt to unforeseen problems.

FOLLOW ON WORK

38. As a postscript to the successful completion of the CLASS sight acceptance tests, DLR and DASPM have initiated a follow on program to improve the accuracy of the Carl Gustav by investigating the issue of ammunition performance with respect to dispersion and with particular emphasis on proofing and muzzle velocity. The plan is to let a contract for this undertaking with DGOR / CORT continuing to act as statistical consultant.

CONCLUSIONS

39. The series of ten memoranda presented in this report document the gradual progress towards a solution to the problems encountered in the acquisition of the CLASS sight for the Carl Gustav weapon. Problems with boresight retention were the initial focus of attention but these were quickly displaced when it became evident that there were serious accuracy issues associated with firing at short range and low ammunition temperatures. Both problems were finally overcome, but it required hard work, patience, and spirit of cooperation of all the individuals involved in the project.

40. In addition to documenting the issues involved in solving the specific technical aspects of the CLASS sight acceptance procedure, this report provides an illustrative case history of the nature of statistical consultation in DND. Lessons learned include the importance of having a sound theoretical knowledge of statistics, backed up by practical experience and a flexible analysis tool such as SAS; and the advisability of having the statistical analyst attend the trials whenever possible. Also of importance are the ability to communicate clearly both verbally and in writing, in order to minimize misunderstandings and produce practical and sound analyses. Openness and professional competence are vital in fostering a relationship of trust and cooperation with all parties involved in order to find positive solutions to difficult problems.

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This project report was written to document the statistical consultation provided over a period of two years on the final stages of the acquisition of a laser sight for the Carl Gustav anti-armour weapon. The paper has been structured around a series of internal memoranda which detail the problems encountered and the gradual progress towards a solution. Besides providing a case study of an actual statistical consultancy project, the report includes lessons and experiences which may be of value in future.

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